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A SIMULATION STUDY OF SONAR (SQS-23 TRAM) OVERHAULS ON NAVAL SHIPS

William Lawrence Fulton

United States
Naval Postgraduate School

THESIS

A SIMULATION STUDY OF SONAR (SQS-23 TRAM) OVERHAULS ON NAVAL SHIPS

by

William Lawrence Fulton

April 1970

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A Simulation Study of Sonar (SQS-23 TRAM) Overhauls on Naval Ships

by

William Lawrence Fulton
Lieutenant Commander, United States Navy
B.S., United States Naval Academy, 1962

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
April 1970

ABSTRACT

A demonstration is provided of using the technique of computer simulation for analyzing scheduling problems in Naval Shipyards. A model is formulated for multiple ship, concurrent, sonar (SQS-23 TRAM) overhauls at the Long Beach Naval Shipyard. This model is an extension of PERT and considers the effect of probabilistic activity times and limited personnel resources. The "TRANSIM" simulator is utilized to assist in predicting the ship overhaul times and manpower utilization under different conditions. Two experiments are conducted which consider changes in relative overhaul commencement dates and modifications to the personnel resource levels. A complete description of the conceptual and computer models and the input coding are included in the report.

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I. INTRODUCTION

A. BACKGROUND

The management of a sonar overhaul on a U.S. Navy ship is a task of extreme complexity. The standards for quality are high, the work is expensive, and operating schedules often impose difficult completion dates. However, the material readiness of the Fleet requires that each of these problems be addressed and satisfactorily resolved by the engineering community.

Quality standards for maintenance work have been established as engineering specifications now in common use. However, the cost and the time elements of this problem are more complex in nature.

The largest single factor in the cost of shipyard work is the cost of direct labor. This factor in turn is heavily influenced by many uncertainties which are inherent in overhaul work aboard naval ships. Work schedules are dependent upon changing fleet operating schedules. The exact scope of the repair work to be performed is usually difficult to establish. The availability of manpower is frequently in doubt because of changing personnel ceilings and other conditions beyond the control of shipyards. All of these factors make the efficient planning and utilization of manpower most difficult. These several areas of uncertainty contribute to the problem of time and cost management.

Because of the substantial funds involved and the sheer complexity of this management problem, this field is a fruitful one for analysis in depth. Any approach through which these vagaries in the work load of a shipyard can be better analyzed and the effects of administrative action better predicted will contribute substantially to improved manpower management and cost control.

B. DESCRIPTION OF THE SONAR OVERHAUL

In order to improve the combat effectiveness of U.S. Navy ships, new innovations offered by advancing technology must be periodically incorporated into existing electronics and weapons systems. The most common sonar system in destroyers today, the SQS-23, was installed a decade ago. Since then, research and development efforts in the design of anti-submarine warfare equipment, coupled with operating experience acquired on this system, have led to major modifications to the SQS-23 in order to enhance its capability. A navy-wide program for the purpose of updating the SQS-23 sonar on each of approximately 170 destroyers was initiated in 1966 and assigned the project name TRAM (Test Reliability and Maintainability).

The TRAM ship alteration is normally performed during a ship's regular overhaul and consumes approximately 13,000 manhours of direct labor. This constitutes about one-eighth of the total labor in the only major overhaul in the ship's three year operating cycle. This overhaul is nominally a three month overhaul, although in recent years the actual length has had a tendency to be slightly longer because of both the increasing age of the ships and the increasing complexity of the installed machinery and electronics equipment. The TRAM modification requires approximately fourteen weeks for completion and, consequently, often becomes the controlling job in determining the ship's departure date. Because vessels in a shipyard are not a part of the inventory of ready military strength, operational commanders are reluctant to make their units available for overhaul periods longer than is absolutely necessary. A responsibility is placed on the overhauling activity to provide a quality product, on schedule, and free from cost overruns.

The Long Beach Naval Shipyard has accomplished TRAM overhauls on approximately seventeen ships of the most common destroyer class. In May 1969 the Shipyard was confronted with the problem of scheduling three ships in quick succession for the TRAM conversion. The Shipyard had had limited experience in performing multiple-ship, simultaneous conversions of this nature. The problem which management faced was to determine a good interarrival time for the ships. Operational commanders desired to make their ships available for overhaul during the same period. However, the personnel resources of the Shipyard were limited and could not accommodate all ships simultaneously without increasing the time that the ships must spend in the Shipyard.

An experienced "judgement decision," was made by Shipyard management that a good interrarrival time would be two weeks. Additionally, it was suggested that computer simulation be employed in order to investigate alternative solutions which might be more advantageous. The time required to collect data, formulate an appropriate model, conduct experiments, and analyze results precluded the implementation of any of the recommendations of the study at that time. However, an understanding of such an analysis may suggest that computer simulation can be fruitfully employed in some future similar situation.

C. OBJECTIVE

It is the purpose of this study to investigate the merits of alternative courses of action available to the manager of the TRAM overhaul. Specific alternatives investigated include modifying the ship interarrival period and altering the available personnel resources.

In the light of the managerial problem previously presented, it is an additional objective of this study to explore the value of computer simulation in improving ship overhaul scheduling and manpower utilization in fleet maintenance work performed by Naval Shipyards.

D. ORGANIZATION OF PAPER

The organization of this paper follows the general organization of the study, which was to define the system, formulate conceptual and computer models, perform experimentation, analyze the results, and draw conclusions.

In Chapter II the system under consideration is described. This system includes both the TRAM project and the shipyard environment to which the sonar overhauls are inextricably associated.

Chapter III discusses the formulation of the conceptual model which represents the actual system. Details include the identification of the system's salient features which are incorporated into the model, assumptions, and type of data accumulated.

Chapter IV initially provides a brief description of the "TRANSIM" simulator, employed in the computer model. The assumptions are stated and the mechanics of transforming the conceptual model into a single ship computer model are discussed. The validity of this computer model is demonstrated. Finally, the extension is made to a triple ship computer model.

In Chapter V the experiments conducted utilizing the computer model are described. An explanation is offered for selecting certain alternative scenarios for specific investigation. The results of the experimentation are summarized and discussed.

Chapter VI presents conclusions and identifies potential areas for further investigation.

II. THE ACTUAL SYSTEM

A. SHIPYARD ENVIRONMENT

A naval shipyard is a complex industrial activity which conducts specific ship repairs, general overhauls, ship conversion, and, occasionally, new construction. Among the echelon of repair activities which might include self-repair, naval tenders, facilities and shipyards, a shipyard has the greatest capability with its extensive physical facilities and highly trained civilian workmen.

The Long Beach Naval Shipyard employs a total of approximately four thousand men in the following groups and shops:

Mechanical Group

- x38 Outside Machine Shop
- x31 Inside Machine Shop
- x56 Pipefitter Shop

Electrical Group

- x36 Weapons and Fire Control Shop
- x51 Electric Shop
- x67 Electronics Shop

Structual Group

- x11 Shipfitter Shop
- x17 Sheetmetal Shop
- x26 Welding Shop
- x41 Boiler Shop

Service Group

- x64 Woodworking Shop
- x71 Paint Shop
- x72 Rigging Shop

Within each shop, personnel are assigned to work centers which specialize in particular areas. For example, in the electronics shop (x67) work center 13 concentrates solely on sonar equipment, while work center 10 is concerned only with radar installations. In Appendix C a description is given of the work accomplished by the various work centers involved in the TRAM overhaul.

Management employs a system of workload forecasting which identifies periods of disparity between projected workload and projected personnel resources. When such situations develop, schedules may be altered, work may be reassigned among repair activities, and personnel may be hired or released. Extra personnel carried on the register constitute an overhead cost. On the other hand, if there are insufficient employees and if excessive maintenance cannot be met by means of overtime, then delays in ship completion dates develop.

At any given time there may be as many as several dozen ships in the shipyard. Their associated maintenance may extend from a single job requiring the services of a small number of highly aligned work centers to a general overhaul or conversion requiring a wide diversity of trades. Work requirements on all ships compete for the personnel resources of the various shops. Operational commanders establish and constantly reevaluate priorities among ships. It is truly a dynamic situation, sensitive to many influences. For example, an aircraft carrier may be damaged by a fire at sea and require immediate repairs at the expense of progress on other ships. Occasionally, unforseen complications such as procurement problems, disclosure of the need for additional repairs, or weather complications develop which may delay certain segments of an overhaul.

The physical layout of ships dictates that close cooperation be maintained among the various shops performing the work. For example, delicate electronic equipment cannot be connected while structual work requiring welding is being performed in the same compartment, because the blinding arc and toxic gases preclude other personnel from working effectively nearby. Consequently, the performance of tasks which initially appear to be independent may actually be quite related.

B. DESCRIPTION OF THE TRAM OVERHAUL

The TRAM overhaul of the SQS-23 sonar consists of two types of work. First, improvements in system design and hardware capabilities dictate that many of the original equipment consoles be replaced. And secondly, those components which are not replaced are completely refurbished.

Some preliminary tasks on project activities may be performed prior to the ship's arrival in the shipyard. Planning personnel may travel to the ship and conduct preliminary inspections in order to assess the initial condition of the sonar and to prepare minor modifications to the standardized overhaul package because of situations inevitably unique to a given ship. In addition, preliminary work can be performed in the shipyard's shops. Such work might include prefabricating piping or sheet metal units, cutting electric cables to the proper lengths, and bench testing electronics consoles which will subsequently replace existing equipment.

Aside from these preliminary activities work performed on the ship in the shipyard can be conveniently classified into three phases:

Phase I: Removal of existing equipment and preparation of the ship's spaces for new equipment.

Phase II: Installation and connecting of new equipment

Phase III: Trouble shooting, testing and certification of the system.

Phase I consists of extensive electrical and structual work. The electric wires and cooling water piping between installed consoles is disconnected. Accesses must be cut through decks and bulkheads. Ventilation ducting, firemains, and hotel service lines must be removed. Equipment is removed, foundations are relocated, and electric cables are routed through the ship.

In Phase II the new equipment is installed. Electrical and piping connections are completed. Wire checks for proper connections between the consoles are conducted. Disrupted ventilation ducting, lighting and hotel service lines are restored. Access through decks and bulkheads can be closed.

Phase III consists of lighting off, testing, calibrating, and certifying the total installation. Finally, decks are tiled and compartments are painted prior to departing from the shipyard.

The TRAM project network is given in Appendix A and a description of activities is given in Appendix F.

III. DEVELOPMENT OF THE CONCEPTUAL MODEL

A. GENERAL METHODOLOGY

Fundamental to the formulation of a model which represents a triple ship TRAM overhaul is a thorough understanding of the single ship TRAM overhaul. After studying the available documentation on TRAM, knowledgable individuals with previous experience in the overhaul were interviewed. Personnel concerned included the Shipyard Production Officer, planners and estimators, representatives from the Methods & Standards Branch, shop general foremen, foremen, and workmen. Firsthand experience was acquired by observing an overhaul in progress. Upon completion of the data acquisition phase, a single ship model was developed. This model was discussed with key personnel and modified until there was general agreement that the important characteristics of the actual system were represented by the model. The model was then extended by superposition to include three ships. The single ship models are interwoven in that the sonar consoles removed from one ship become the new equipment installed in the subsequent ship after the consoles are refurbished and design improvements are incorporated. In addition, the individual tasks compete with one another for the limited personnel resources.

B. SELECTION OF A METHOD OF ANALYSIS

In order to study the behavior of a system in the performance of a project, management can employ several techniques. The Critical Path Method (CPM) will provide an analysis using deterministic service times. Program Evaluation and Review Technique (PERT) will provide an analysis using the expected value of an approximation to a Beta distribution of service times for each activity.

Through the use of Monte Carlo techniques, an improved approximation to the actual system behavior can be achieved. By associating a probability distribution of service times with each activity in the network, then a particular realization of the service times of the network can be accomplished by drawing a service time for each activity from these distributions. This realization can then be treated as a deterministic critical path problem, and such things as the critical path and the overall project completion time can be computed. By repeating this procedure a number of times, the distributions of variables of interest (e.g. overall project completion time) of the system are obtained. Better managerial decisions can be based on these distributions. Reference 1 expands on the application of Monte Carlo methods to the PERT problem.

An additional refinement to the above technique is to consider limited personnel resources and to allow delays to occur because of the unavailability of these resources. This refinement is incorporated in the model developed here, also.

C. ASSUMPTIONS

The following assumptions were made in developing the conceptual model for the TRAM overhaul:

1. Independent Activity Times

In the TRAM overhaul, recovery from an unanticipated delay can be made by administratively increasing the manning on a subsequent activity and thereby decreasing its activity time. The model assumes that the covariance between all activities is zero and consequently cannot incorporate such "administrative adjustments." Not only is independence assumed between activities on the network for a given ship, but also between ships for the multiple ship model.

2. Interface with Remainder of Shipyard Work

A comprehensive model would also include the remainder of the shipyard work. However, because of the complexity of designing such a model and accumulating the associated data an alternate representation was made. The primary interface between the TRAM overhaul and other work consists of competition for repair personnel. The total resources in each of the work centers is known. By using historical data which relates the percentage of total shop manpower used on a ship undergoing TRAM, and subtracting the resources associated with non-TRAM work on that ship, a good indication of the resources which would be available for work on the TRAM project was provided.

3. Limitations on Plant Resources

It is considered that the physical facilities of a shipyard are sufficient to adequately support the TRAM overhaul. For example, it is not anticipated that delays would be encountered because of unavailability of cranes, test benches, dry docks, or the ship's unique electrical power necessary for the sonar checkout phase.

4. Delays Due to Inadequate Supply Support

Interviews suggested that delays due to supply unavailability were infrequent and not repeatedly associated with the same equipment or components and could therefore be disregarded.

5. Availability of "Spare Set" of Sonar Consoles

It is assumed that initially a spare set of sonar consoles exists in the shipyard's inventory and it is ready for installation in the first ship of the three ship model as soon as the old equipment is removed. The old equipment is then refurbished, the major design modifications are made, and that set becomes the spare set for the subsequent ship.

6. Manning Intensities for Supporting Shops

The manning intensity for supporting shops was determined from data made available by the Methods and Standards Branch. It is assumed that if the probabilistic nature of the activity time extends the total man-days contributed by the lead shop, then the number of man-days contributed by each of the supporting shops will be extended in the same ratio as their original contribution.

D. FORMULATION OF THE CONCEPTUAL MODEL

In the conceptual model each individual activity of the TRAM project network can be treated in the following general sequence:

1. Establish a requirement to accomplish a task
2. Assign personnel to the task
3. Allow passage of the time required to perform the task
4. Return personnel to the manpower pools
5. Generate subsequent task requirements

The following example of the sequential operations involved in disconnecting an equipment console is depicted in Figure 1.

A requirement exists to disconnect the equipment. This may exist physically in the form of a written work request or conceptually in the mind of the foreman. When personnel with the specific skills (electricians, mechanics, and laborers) become available they are assigned to do the work. After the passage of a probabilistically determined period, the work is considered to be completed. The electricians, mechanics, and laborers are returned to their respective shop pools for reassignment. Upon the completion of other parallel tasks, for example, the opening of accesses, a new requirement is generated to remove the equipment. This task is then treated similarly. Work progresses sequentially until all activities in the network have been completed.

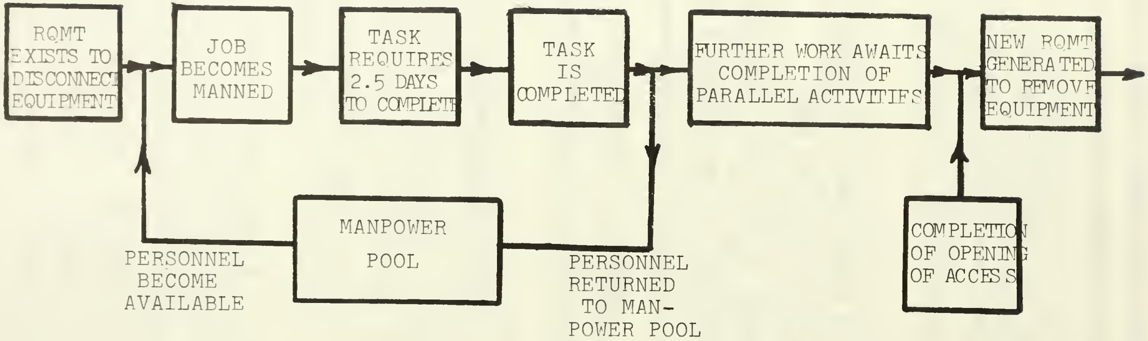

RQMT EXISTS TO DISCONNEC EQUIPMENT
JOB BECOMES MANNED
TASK REQUIRES 2.5 DAYS TO COMPLET
TASK IS COMPLETED
FURTHER WORK AWAITS COMPLETION OF PARALLEL ACTIVITIES
NEW RQMT GENERATED TO REMOVE EQUIPMENT
MANPOWER POOL
PERSONNEL BECOME AVAILABLE
PERSONNEL RETURNED TO MAN-POWER POOL
COMPLETIO OF OPENIN OF ACCESS

Figure 1. The Conceptual Model

E. DATA COLLECTION

During interviews each activity was discussed in detail and information of the following nature was accumulated:

1. Exact precedence relationship to other activities
2. Distribution of activity times
3. Policy regarding manning intensity

IV. DEVELOPMENT OF THE COMPUTER SIMULATION MODEL

A. USE OF THE "TRANSIM" SIMULATOR

The primary benefit of computer simulation is that it makes it possible to evaluate a spectrum of situations without suffering the consequences of committing actual resources in an inefficient manner. Once the most desirable solution is determined by experimenting with the computer model, that solution may then be implemented in the actual system.

"TRANSIM" is a simulation program developed at The University of California, Los Angeles [2], initially to simulate transportation systems. Its application has since been extended to other areas, including scheduling and resource allocation.

A conceptual model is transformed into a "TRANSIM" computer model by specifying the appropriate input data, which includes:

1. A description of the system's operating characteristics, i.e., precedence rules for the network. In "TRANSIM" terminology these are called conversion rules.
2. A probability distribution of time for each of the activities in the model. These are called service time distributions and are located after the conversion rules in the input coding.

3. A listing of the resources available to perform the operations described by the conversion rules. These appear in the "EVENTS" section of the input coding.

Output summaries available for analysis include time reports and load reports. The former summarize the time requirements and delays encountered while performing the various tasks in the project network. The latter summarize the intensity of manpower utilization for the duration of the project. Examples of time and load reports are shown in Figures 2 and 3.

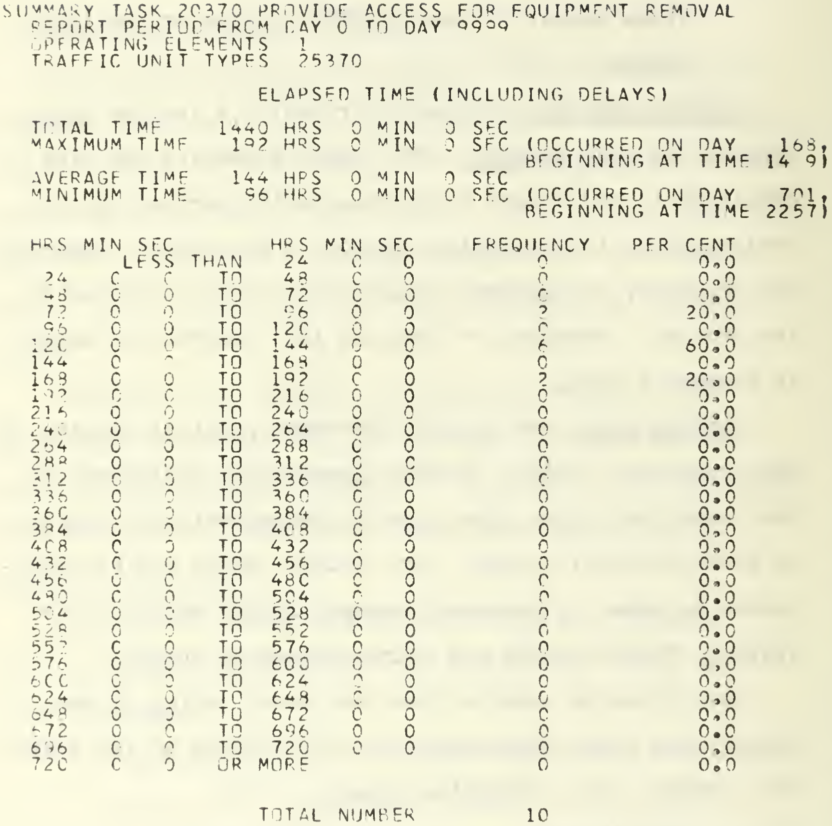
Traffic units are used to represent physical objects in the conceptual model. Through appropriate employment of the conversion rules, they acquire characteristics similar to these physical objects. The traffic units may be manipulated in order to represent changes in the state of the system. Traffic units are characterized by numbers.

The following examples from the input coding of the single ship model demonstrate the use of each of the available traffic unit conversion rules:

1. Substitution

   $(6581) \overset{S}{\rightarrow} (582) + (583)$

   Every traffic unit of type 6581 is transformed into a traffic unit of type 582 and another of type 583. The traffic unit of type 6581 is eliminated from the system after the operation. This type of



```
SUMMARY TASK 20370 PROVIDE ACCESS FOR EQUIPMENT REMOVAL
   REPORT PERIOD FROM DAY 0 TO DAY 9999
   OPERATING ELEMENTS  1
   TRAFFIC UNIT TYPES  25370

                      ELAPSED TIME (INCLUDING DELAYS)

   TOTAL TIME      1440 HRS  0 MIN  0 SEC
   MAXIMUM TIME     192 HRS  0 MIN  0 SEC (OCCURRED ON DAY   168,
                                          BEGINNING AT TIME 14 9)
   AVERAGE TIME     144 HRS  0 MIN  0 SEC
   MINIMUM TIME      96 HRS  0 MIN  0 SEC (OCCURRED ON DAY   701,
                                          BEGINNING AT TIME 2257)

   HRS MIN SEC          HRS MIN SEC      FREQUENCY   PER CENT
          LESS THAN      24   0   0          0          0.0
    24    0    0    TO   48   0   0          0          0.0
    48    0    0    TO   72   0   0          0          0.0
    72    0    0    TO   96   0   0          2         20.0
    96    0    0    TO  120   0   0          0          0.0
   120    0    0    TO  144   0   0          6         60.0
   144    0    0    TO  168   0   0          0          0.0
   168    0    0    TO  192   0   0          2         20.0
   192    0    0    TO  216   0   0          0          0.0
   216    0    0    TO  240   0   0          0          0.0
   240    0    0    TO  264   0   0          0          0.0
   264    0    0    TO  288   0   0          0          0.0
   288    0    0    TO  312   0   0          0          0.0
   312    0    0    TO  336   0   0          0          0.0
   336    0    0    TO  360   0   0          0          0.0
   360    0    0    TO  384   0   0          0          0.0
   384    0    0    TO  408   0   0          0          0.0
   408    0    0    TO  432   0   0          0          0.0
   432    0    0    TO  456   0   0          0          0.0
   456    0    0    TO  480   0   0          0          0.0
   480    0    0    TO  504   0   0          0          0.0
   504    0    0    TO  528   0   0          0          0.0
   528    0    0    TO  552   0   0          0          0.0
   552    0    0    TO  576   0   0          0          0.0
   576    0    0    TO  600   0   0          0          0,0
   600    0    0    TO  624   0   0          0          0.0
   624    0    0    TO  648   0   0          0          0.0
   648    0    0    TO  672   0   0          0          0.0
   672    0    0    TO  696   0   0          0          0.0
   696    0    0    TO  720   0   0          0          0.0
   720    0    0    OR MORE                 0          0.0

                      TOTAL NUMBER           10
```

Figure 2. Sample Time Report

```
    SUMMARY  WORKCENTER 6713 AVAILABLE (UNASSIGNED) MANPOWER
      REPORT PERIOD FROM DAY 0 TO DAY 9999
      OPERATING ELEMENTS  1
      TRAFFIC UNIT TYPES  46713


    NUMBER DELAYED OR IDLE                  TOTAL NUMBER IN SERVICE, DELAYED, OR IDLE

TOTAL NUMBER IN REPORT PERIOD      715    TOTAL NUMBER IN REPORT PERIOD     1291
MAXIMUM       20 (ON DAY       0 AT  0 1,  MAXIMUM       20 (ON DAY       0 AT  0 1,
                 AND ON  24 OTHER TIMES)                    AND ON  24 OTHER TIMES)
AVERAGE       1.54                         AVERAGE       1.54
MINIMUM        0 (ON DAY       0 AT  0 0,  MINIMUM        0 (ON DAY       0 AT  0 0,
                 AND ON  43 OTHER TIMES)                    AND ON  53 OTHER TIMES)
    NUMBER    PERCENT OF REPORT PERIOD         NUMBER    PERCENT OF REPORT PERIOD
      0                0.4                       0                0.4
   1 THRU   1          0.0                    1 THRU   1          0.0
   2 THRU   2          1.7                    2 THRU   2          1.7
   3 THRU   3          0.4                    3 THRU   3          0.4
   4 THRU   4          0.0                    4 THRU   4          0.0
   5 THRU   5          0.6                    5 THRU   5          0.6
   6 THRU   6          0.1                    6 THRU   6          0.1
   7 THRU   7          0.3                    7 THRU   7          0.3
   8 THRU   8          1.1                    8 THRU   8          1.1
   9 THRU   9          0.6                    9 THRU   9          0.6
  10 THRU  10          0.8                   10 THRU  10          0.8
  11 THRU  11          0.0                   11 THRU  11          0.0
  12 THRU  12          1.5                   12 THRU  12          1.5
  13 THRU  13          0.4                   13 THRU  13          0.4
  14 THRU  14          0.0                   14 THRU  14          0.0
  15 THRU  15          2.2                   15 THRU  15          2.2
  16 THRU  16          0.1                   16 THRU  16          0.1
  17 THRU  17          0.9                   17 THRU  17          0.9
  18 THRU  18          0.3                   18 THRU  18          0.3
  19 THRU  19          0.0                   19 THRU  19          0.0
  20 THRU  20         88.4                   20 THRU  20         88.4
     OVER  20          0.0                      OVER  20          0.0
```

Figure 3. Sample Load Report

conversion rule is used to "start" activities 582 and 583 after the completion of activity 6581.

2. Consolidation

$(6350) + (6393) \xrightarrow{C} (431)$

One traffic unit each of type 6350 and 6393 join and form a single unit of type 431. This rule indicates that activities 6350 and 6393 must both be completed before activity 431 may begin. Consolidation rules are also used to express resource requirements. For example, if unmanned activity 429 required seven electricians in order to become a manned activity, the rule would be written:

$$(429) + 7(45120) \xrightarrow{C} (5429)$$

3. Generation

$(6601) \xrightarrow{G} (43607) + 4(47205) + 6(45120)$

A traffic unit of type 6601 creates one traffic unit of type 43607, four units of type 47205, and six units of type 45120. The original traffic unit remains in the system after the operation, constituting the distinction between substitution and generation. This type of rule is used to return personnel to their respective manpower pools upon completion of a particular activity.

4. Breakdown

Resources are introduced as a single traffic unit consisting of sub units. For example, twelve men from Shop 67, Work Center 13 (Sonar Repair) are introduced as a single traffic unit which must be broken down into sub-units by either one of two conversion rules:

a) $(46713) \overset{B}{\rightarrow} (46713) + (46713) + \quad + (46713)$
(total of 12 sub-units)

The traffic unit of type 46713 is broken down into its twelve sub-units. This type of rule is not as convenient as rule b) below when breaking down personnel resources. However, it is used to break down the type 999 traffic units used in the iteration counter, as will be discussed in Section IV,D.

b) 400024 B

This global breakdown conversion rule is used for convenience when many traffic unit types with similar numbers are to be broken down. In order to interpret the rule, consider that all traffic unit type numbers are six digits long. In this example, if a 4 exists in digit 2 of the traffic unit type number, then it is to be broken down. Example: A traffic unit of type 46713 (actually 046713) would be broken down into all of its sub-units because a 4 exists in the second digit from the left.

"TRANSIM" input coding procedures do not require that the network traffic unit conversion rules be grouped in any particular sequence. Continuation cards for any given rule must, however, follow in order.

B. GENERAL METHODOLOGY

As in the formulation of the conceptual model discussed in Chapter 3, it is important to have a properly represented single ship computer model before an extension to a three ship model can be made. In order to achieve this, the traffic units in the conceptual model (work requests, shop personnel, manned activities, etc.) were assigned traffic unit type numbers. The numerous interactions between these entities were described by the traffic unit conversion rules and service times. Initial runs verified that the model was operating as desired and that the results seemed to be in consonance with the input conditions. Confidence that the single ship computer model behaved in a fashion similar to the actual system was gained by the favorable comparison between the results of the computer model and historical data. (A detailed discussion of the technique employed in validating the single ship model appears in Section IV,E). With the single ship model as a foundation, the triple ship computer model was then formed.

C. ASSUMPTIONS

The following assumption were made in developing the computer model for the TRAM overhaul:

1. Variable Number of Shifts

Occasionally, manning intensities are such that two or three 8 hour shifts are assigned per day vice the normal one. This problem is conveniently handled by considering that the manning on the activity is correspondingly doubled or tripled for a single shift.

2. Breakdown of Manning Requirements on Activities Requiring Heavy Manning

The mechanics of the "TRANSIM" simulator dictate that no activity can commence its activity time until all of the required traffic units have been assembled. For example, if eighteen men are required to install electrical cables and only seventeen men are available, no action is taken until the final man is released by another activity. In reality, some work would be performed by at least a smaller group of men in order to reduce the overall delay. In order to overcome this property of the simulator, all activities requiring over ten men have been described in terms of multiple parallel activities, the sum of whose requirements equal the original total requirements. Figure 4 demonstrates this vertical stratification.

3. Breakdown of Complex Activities

Activities of a complex nature were stratified horizontally in order to improve the representation in the model. For example, the task of connecting the consoles after positioning in the ship was broken up in order to permit some connections to be made as soon as the equipment

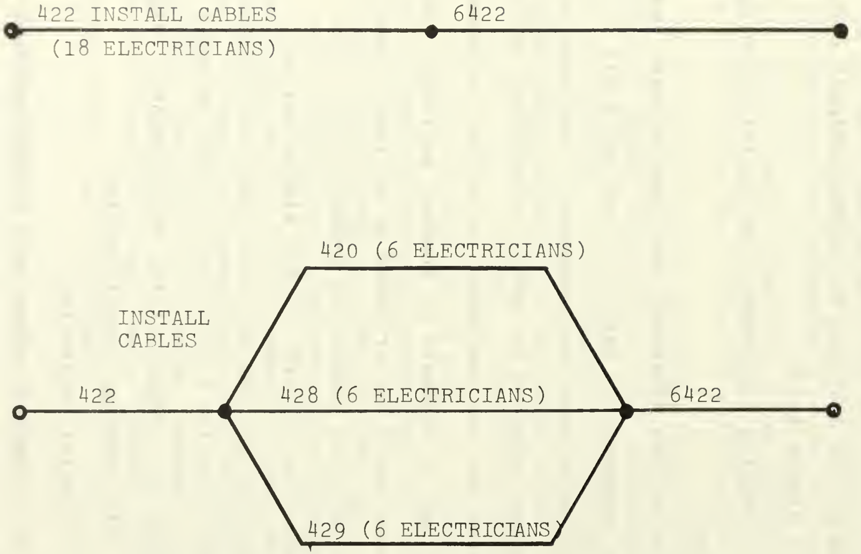


Figure 4. Breakdown of Activities with Heavy Manning

is in place, and yet to allow other connections to be made later after the initial connections have been wire-checked for correctness. This sequence is displayed in Figure 5.

4. Level of Detail

The original level of detail modelled contributions of personnel by as small as a tenth of a man for the duration of any activity time. Initial computer runs for the triple ship model required approximately twenty minutes for the first iteration on the IBM/67 (slightly less time was required for subsequent iterations because of the initial fixed time inherent in the simulator).

The amount of confidence in the results is related directly to the number of trials performed. The larger the sample size, the greater is the information available concerning the central tendency and variability of the model's response. Therefore, in order to achieve a sample size of ten within the computer time available, the running time per iteration had to be reduced to approximately 2½ minutes. This was accomplished by reducing the number of traffic units in the computer model. The final representation of a minimum of one man contributing labor for the duration of the service time was a compromise which represented a reduction in the original level of detail but which bought greater statistical confidence in the results because of the larger sample size.

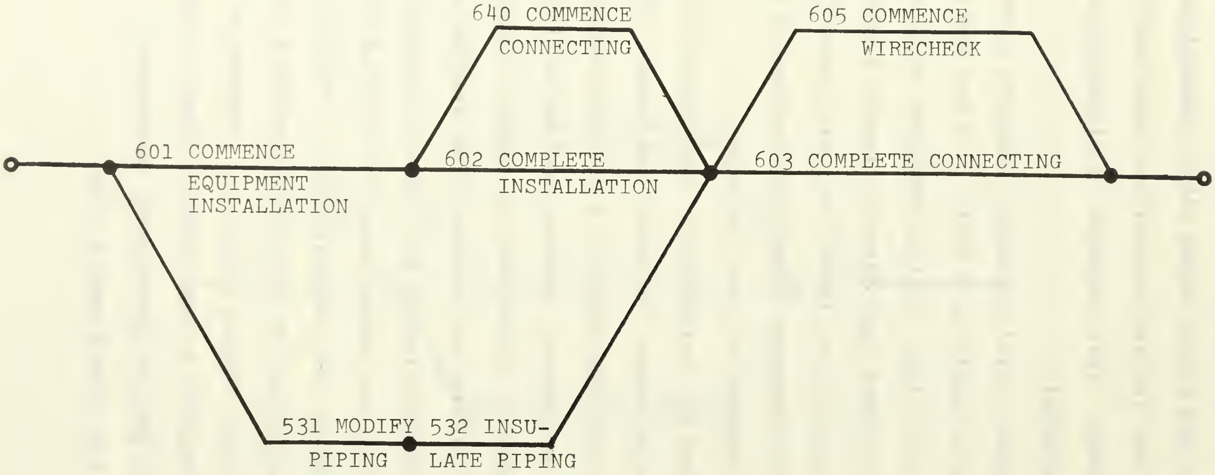


Figure 5. Breakdown of Complex Activities

5. Nature of Personnel Resources

In order to greatly facilitate the design of the computer model the level of personnel resources was considered to be constant throughout the simulation.

The number of personnel assigned to each manpower pool was a judgment decision based on shipyard experience and the following three considerations:

a) The minimum number required to satisfy the mechanics of the computer model, i.e., meet the minimum individual demands of each of the traffic unit conversion rules

b) The maximum number available in the actual system

c) The probable number that would be available to work on the TRAM overhaul, considering the requirements of other shipyard work.

The constraints and number assigned are shown in Table I.

D. DESIGN OF THE SINGLE SHIP COMPUTER MODEL

The five discrete steps of the conceptual model outlined in Section III,D will now be represented utilizing numbered traffic unit types and the conversion rules introduced in Section IV,A. The following example appears in the single ship input coding. Traffic unit type numbers represent specific conditions.

Traffic Unit of Type	Condition
380	A requirement (possibly a written job order) to disconnect the installed sonar consoles

Traffic Unit of Type	Condition
581	A requirement to install the consoles in the shop for overhaul
5380	The consoles being disconnected are completely manned
6380	The consoles have been disconnected and moved
6370	The condition in which the accesses on the ship have been opened
43607	Mechanics skilled in disconnecting structures
45120	Electricians skilled in disconnecting wires
47205	Laborers capable of moving the heavy consoles

By using the appropriate conversion rules, transformations can be made between traffic units. A traffic unit of type 380 will consolidate with 10 traffic units of type 45120 (indicating ten electricians), plus 4 traffic units of type 43607, plus 7 traffic units of type 47205 to form a manned activity, represented by a traffic unit of type 5380. The original traffic units of type 380, 45120, 43607, and 47205 and destroyed. After the passage of the service time which is determined probabilistically from the cumulative distribution functions introduced as input data, say 2.3 days, the job is considered to be complete and the traffic unit of type 5380 substitutes into a traffic unit of type 6380. Again, the previous traffic unit (of type 5380) is destroyed. After the task has been completed, the personnel must be returned to the manpower pools and

TABLE I

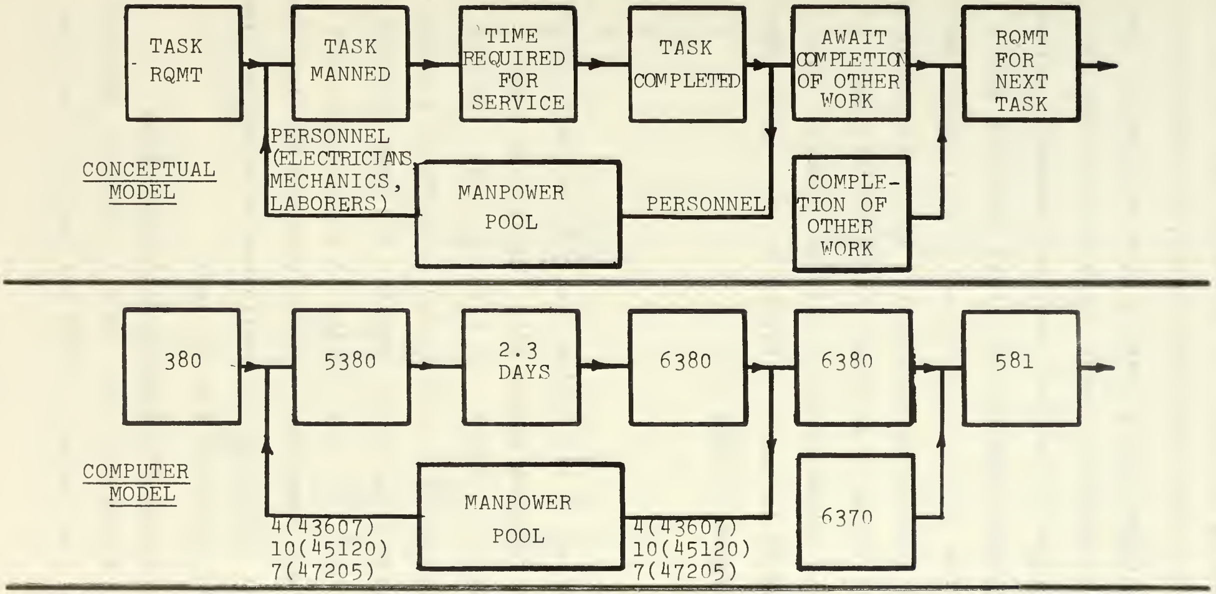
WORK CENTER PERSONNEL CONSTRAINTS AND ASSIGNMENTS

Shop/Work Center		Minimum Required	Maximum Available	Number Assigned
11	01	2	12	2
11	04	1	41	1
11	05	3	67	3
11	06	4	77	6
17	01	1	12	1
17	02	1	30	1
17	03	4	31	4
17	04	3	30	3
17	05	4	64	4
26	01	1	40	1
26	05	4	182	6
31	07	2	23	2
36	07	4	90	4
36	10	1	63	1
51	01	3	19	3
51	03	6	27	6
51	08	2	32	2
51	11	2	25	2
51	20	10	215	12
56	05	1	72	1
56	06	4	203	4
64	06	6	165	6
67	13	8	26	12
71	02	1	31	1
71	03	1	14	1
71	04	8	46	8
72	02	3	126	3
72	05	7	207	7
Code	135	2	8	2
Code	290	2	8	2

made available for other work. Therefore, the traffic unit of type 6380 will generate the original personnel that the traffic unit of type 380 absorbed i.e., 10(45120) + 4(43607) + 7(47205) traffic unit types. Note that the traffic unit of type 6380 has not yet been flushed from the system. It awaits consolidation with parallel traffic unit types after their activities have been completed. In this case, as soon as the accesses have been opened in order to permit the removal of the equipment, a traffic unit of type 6370 will be created in a similar fashion. The consolidation of traffic units of type 6380 and 6370 into one of type 581 indicates a new requirement to install the consoles in the shop for overhaul. This sequence of events is indicated in Figure 6.

Output summaries would be affected by the above sequence in two ways. First, the individual work center load reports would reflect the use by this activity of the 10 electricians, the four mechanics, and the seven laborers each for a period of 2.3 days. Secondly, the time reports would indicate the time required to perform the task of disconnecting the equipment and the time that progress was delayed while waiting for the accesses to be opened.

The number of iterations of the simulation can be controlled by absorbing one traffic unit of a unique type during every iteration until the supply of that unique type is depleted. For example, a traffic unit of type 999



INPUT CODING

```
(380)+ 4(43607) + 10(45120) + 7(47205) G (5380)
(5380) S (6380)
(6380) G 4(43607) + 10(45120) + 7(47205)
(6380) + (6370) C (581)
```

Figure 6. Development of Input Coding

consisting of thirty sub-units is introduced as a resource. After breaking down into individual units, the first sub-unit will consolidate with a traffic unit of type 710 (the "job starter") in order to create a new unit of type 997 which will initiate all original task requirements. After the project has been completed the final operation will recreate a traffic unit of type 710 which will consolidate with the second type 999 traffic unit. After the supply of type 999 traffic units is depleted the simulation will terminate and the summary results will be printed. This iterative procedure is shown in Figure 7. The single ship input coding appears on page 102.

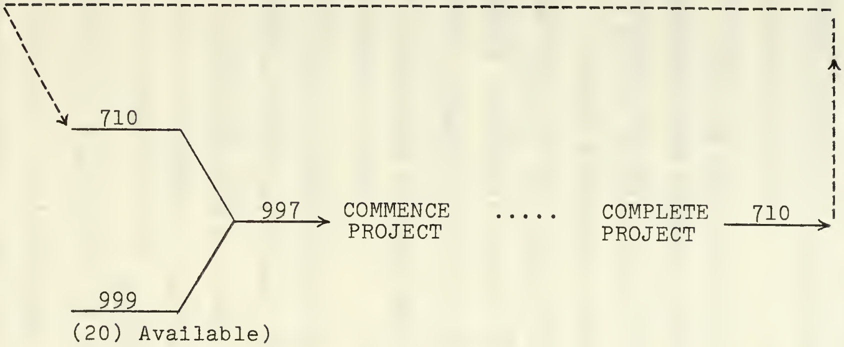
E. VALIDATION

1. Purpose

The purpose of validating the computer model is to insure that its response agrees with that of the actual system under similar stimuli. In both the model and the system, the response will be measured in terms of a distribution of the time required to complete the TRAM overhaul. The extent to which the distribution of the results from the computer model agree with the distribution of historical data will permit a statistical confidence to be established that the two distributions are the same.

2. Assumptions Concerning the Historical Data

Several assumptions were made in order to associate data concerning the history of TRAM overhauls at the Long



(999) B

(710) + (999) C (997)

(690) + (700) + ... + (650) C (710)

Figure 7. Iteration Counting Mechanism

Beach Naval Shipyard with the results of the computer model. They include:

a. The TRAM overhaul constituted the controlling job on all ships considered. This assumption was necessary because only ship arrival and departure dates were available, which became the TRAM commencement and completion dates.

b. Only destroyers of the same class as those which would undergo the triple ship overhaul were considered. For example, this excluded the consideration of history involving guided missile destroyers because of their different sonar configuration and because the overhaul of the missile system is usually the controlling job. Service times and manning intensities for the TRAM overhaul in these cases would be different from those of non-missile destroyers.

c. One calendar week is the equivalent of six working days. This assumption is considered to be valid in view of the reduced working levels on both Saturdays and Sundays and because of occasional overtime.

3. Reduction of Historical Data

The historical data used in validating the model is listed in Table II. Overhaul commencement and completion dates have been converted to Julian dates, their difference has been determined, and reduced by a factor of $1/7^{th}$ in order to convert calendar weeks to six day work weeks. No compensation has been made for national holidays. It was

TABLE II

HISTORICAL DATA FOR TRAM OVERHAULS

SHIP	START	COMPLETE	DIFFERENCE	WORK DAYS
ROWAN (DD 782)	34	123	89	76
ROGERS (DD 876)	10	100	90	77
EVERSOLE (DD 789)	37	132	95	81
AGERHOLM (DD 826)	259	356	97	83
FECHTELER (DD 870)	189	290	101	87
ANDERSON (DD 786)	245	350	105	90
B. BASS (DD 887)	291	34	108	93
CHANDLER (DD 717)	297	41	109	93
HANSON (DD 832)	187	299	112	96
ISBELL (DD 869)	289	36	112	96
MC KENZIE (DD 836)	266	12	113	97
OZBOURNE (DD 846)	338	87	114	98
RUPERTUS (DD 851)	252	2	115	99
GURKE (DD 783)	90	205	115	99
HOLLISTER (DD 788)	312	63	116	101
TUCKER (DD 875)	266	17	118	101
H. S. THOMAS (DD 833)	274	48	139	119

suspected that the lengthy overhaul time for H.S. THOMAS was caused by work other than the TRAM overhaul. This data point was therefore discarded.

4. Conduct and Results of the Single Ship Computer Run

The single ship model was run for thirty iterations in order to obtain a distribution of overhaul times. This sample size was considered to be sufficiently large to permit a meaningful statistical inference to be made, yet the 22 minutes of computer time required was acceptably small. The overhaul times realized in the thirty iteration computer run are as follows:

DAYS	FREQUENCY
78	1
81	1
84	1
86	1
88	1
89	1
90	1
91	4
92	3
93	4
94	1
95	2
96	1
97	1
98	2
99	2
101	1
102	1
105	1
	30

Minimum = 78 days
Mean = 93.3 days
Maximum = 105 days

5. Selection of Goodness of Fit Test

In order to compare the distribution of the observations from the computer model with that of the actual system, a goodness of fit test was used. Two candidates were considered. The Kolmogorov-Smirnov test was selected in preference to the Chi-Square test because all of the necessary assumptions required for its use were met (Ref. 3, page 59) and it is more powerful. The Kolmogorov-Smirnov test involves a comparison of the cumulative frequency distributions of the observed computer results and the system results. The point at which these two distributions have the greatest divergence is determined. A decision is made regarding the probability of achieving such a divergence if the observations from the computer model were really a random sample from the distribution produced by the actual system. In other words, the hypothesis that the observations from the model could have been drawn from the distribution given by the system is to be tested.

6. The Kolmogorov-Smirnov Goodness of Fit Test

Table III provides information concerning the distributions from the system and the computer model. Associated with each overhaul time are the number of occurrences, the cumulative number of occurrences, and the cumulative distribution function for both distributions. For each overhaul time, the difference between the model and system cumulative distribution functions is shown. A significance level of .01 was chosen. In order to test the hypothesis that the observations from the model could have come from the distribution given by the system, the D value calculated ($D_{calc} = .20$) was compared with the critical value of D

TABLE III

DISTRIBUTION OF COMPLETION TIME FOR THE SYSTEM AND FOR THE COMPUTER MODEL

	SYSTEM			MODEL			
DAYS	# OBS.	# CUM.	CDF	# OBS.	# CUM.	CDF	CDF DIFF.
76	1	1	.0625	0	0	.0000	.0625
77	1	2	.1250	0	0	.0000	.1250
78	0	2	.1250	1	1	.0333	.0920
79	0	2	.1250	0	1	.0333	.0920
80	0	2	.1250	0	1	.0333	.0920
81	1	3	.1875	1	2	.0667	.1208
82	0	3	.1875	0	2	.0667	.1208
83	1	4	.2500	0	2	.0667	.1833
84	0	4	.2500	1	3	.1000	.1500
85	0	4	.2500	0	3	.1000	.1500
86	0	4	.2500	1	4	.1333	.1167
87	1	5	.3125	0	4	.1333	.1792
88	0	5	.3125	1	5	.1667	.1458
89	0	5	.3125	1	6	.2000	.1125
90	1	6	.3750	1	7	.2333	.1417
91	0	6	.3750	4	11	.3667	.0083
92	0	6	.3750	3	14	.4667	-.0917
93	2	8	.5000	4	18	.6000	-.1000
94	0	8	.5000	1	19	.6333	-.1333
95	0	8	.5000	2	21	.7000	-.2000*
96	2	10	.6250	1	22	.7333	-.1083
97	1	11	.6875	1	23	.7667	-.0792
98	1	12	.7500	2	25	.8333	-.0833
99	2	14	.8750	2	27	.9000	-.0250
100	0	14	.8750	0	27	.9000	-.0250
101	2	16	1.0000	1	28	.9333	.0667
102	0	16	1.0000	1	29	.9667	.0333
103	0	16	1.0000	0	29	.9667	.0333
104	0	16	1.0000	0	29	.9667	.0333
105	0	16	1.0000	1	30	1.0000	.0000

*D_{calc} = Maximum Absolute Value of CDF Difference = .2000

determined from Table E of Reference 3 ($D_{crit} = .29$). Since $D_{calc} < D_{crit}$, the hypothesis was accepted.

F. DESIGN OF THE TRIPLE SHIP COMPUTER MODEL

The triple ship computer model is essentially the superposition of three single ship models with the assumption that a spare set of sonar consoles is initially available. They are installed as soon as the set of consoles from the first ship is removed for refurbishing and updating. After overhaul, this set is made available to the next ship whenever it is ready. The evolutions involved in overhauling these consoles are included in the model. Figure 8 shows the interlocked model, including the iteration counter mechanism and the timing traffic units for the individual ships, the overall overhaul period, and some of the phases.

The resources for the triple ship model were set at three times the resources for the single ship model, except for Shop 67, Work Center 13. Its resource level was increased from 12 (single ship model) to 20 because there are only 26 men in that work center, and it was assumed that some of these men would be required by other ships in the Shipyard.

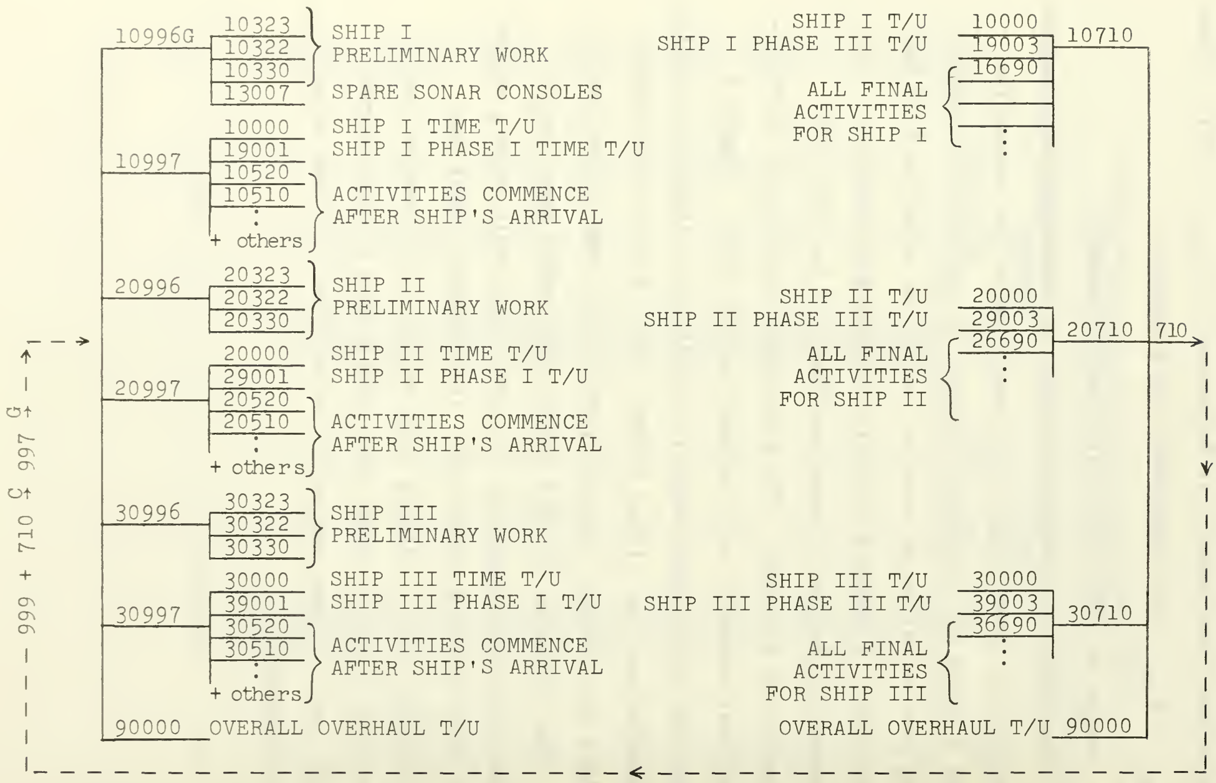


Figure 8. Triple Ship Model

V. EXPERIMENTATION WITH THE MODEL

A. DESIGN OF THE EXPERIMENT

After the single ship computer model had been validated and the triple ship model formulated by superposition, experimentation could be performed in order to analyze the merits of alternative courses of action.

The two primary factors which determine the individual ship and overall overhaul times are:

1. The interarrival time between the ships, and
2. The amount of personnel resources available to perform the overhaul.

Two experiments were conducted to examine the effects of these factors. In Experiment A, six interarrival periods utilizing identical personnel resources were investigated. Ships were made to arrive simultaneously, and at one, two, three, four, and five week intervals. In Experiment B, the personnel resources in four work centers were increased slightly in order to investigate the effect of limited resources.

The output reports from the computer provide summaries of the time required to accomplish overhauls as follows:

1. Overall overhaul time
2. Overhaul time for individual ships
3. Overhaul time for each ship for the individual phases defined in Section II,B.

The number of iterations of the simulation for the production runs was determined as a compromise among several factors. It was necessary to conserve computer time, yet desirable to run the simulation long enough to obtain a sample sufficiently large to permit meaningful statistical inferences to be made. The final decision was to perform ten iterations for each scenario, which required about 27 minutes of computer time per scenario.

B. DEFINITIONS AND METHODOLOGY

In order to evaluate alternative scenarios, the following definitions are required:

Overall completion time:
The time required to overhaul three ships, commencing with the arrival of the first ship in the shipyard and ending with the completion of the last ship to depart.

Individual ship completion time:
The time required to overhaul a specific ship.

Total ship-days in the shipyard:
The sum of the number of days required to overhaul each of the three individual ships.

The results of the two experiments performed will be presented in the next two sections. For each experiment, the anticipated results will be explained, followed by a discussion of the actual results. Supporting data in tabular or graphical form will immediately follow the discussion of results for Experiment A and Experiment B respectively.

The procedure used to determine confidence intervals about the means discussed in the results is described in

Appendix D. The mean and standard deviation for variables of interest are tabulated in Appendix E.

Conclusions will be stated in the next chapter.

C. EXPERIMENT A

Ships which arrive in quick succession and have short interarrival periods can be expected to incur delays as they compete among each other for the limited personnel required to perform activities in the project. As the interarrival period is increased, the degree of interaction or dependency between the ships decreases to the limiting situation in which the interarrival time is so great that a ship completes the TRAM overhaul prior to the arrival of the subsequent ship. In this limiting case, the mean individual ship completion time should be the same as the expected completion time for the single ship model, modified to include the same level of resources as the triple ship model. At any time the specific nature of the activities being performed on all ships establishes a level of interaction between the ships. This level depends on the extent to which these activities are competing for resources which are unavailable because of assignment to other ships. If, by adjusting the interarrival period, an environment truly void of interaction can be established, then any increase in interarrival times will be directly reflected as an increase in overall completion time.

The overall completion times for the zero, one, two, and three week interarrival periods had a minimum of 120.7 days and a maximum of 121.9 days as indicated in Table IV. This provided a range of 1.2 days for the four smallest interarrival periods considered. By increasing the interarrival period from three to four weeks, the time required for overall completion was increased by 6.3 days. Likewise, by increasing the interarrival time from four to five weeks, the overall completion time increased from 127.9 to 140.4 days. This increase of 12.5 days is reasonable because the cumulative effect of increasing the interarrival period from four weeks causes Ship III to arrive in the shipyard 12 days (two work weeks) later. Overall completion times for each interarrival period are displayed in Figure 9. Corresponding completion times for the individual ships are displayed in Figure 10.

The total ship-days in the shipyard for each of the interarrival periods is given in Table V and also displayed in Figure 9. A marginal decrease was experienced between subsequent interarrival periods. The magnitude of this decreases becomes sequentially smaller. Figure 11 provides an extrapolation of the results available from experimentation through the five week interarrival scenario. It suggests that the asymptotic total ship-days in the shipyard is approximately 215 or about 72 days per ship. This is less than the mean overhaul time of 93.3 days experienced

TABLE IV

EXPERIMENT A OVERHAUL TIME

INTERARRIVAL PERIOD	0	1	2	3	4	5
Mean Overhaul Completion Time	120.7	121.9	121.3	121.6	127.9	140.3
Marginal Increase		1.2	-0.6	0.3	6.3	12.5
Ship I Overhaul Time	88.3	78.9	79.7	80.4	83.5	81.5
Ship II Overhaul Time	90.2	89.5	84.9	83.4	79.5	77.3
Ship III Overhaul Time	117.2	109.9	97.3	85.6	79.9	80.1

TABLE V

EXPERIMENT A SHIP-DAYS IN THE SHIPYARD

INTERARRIVAL PERIOD	0	1	2	3	4	5
Total of Mean for Individual Ships	295.7	278.3	261.9	249.4	242.9	238.9
Marginal Decrease		17.4	16.4	12.5	6.5	4.0
Average of Mean Time for Three Ships	98.4	92.6	87.2	83.1	81.0	79.7
% Decrease from Value for Simultaneous Arrival	0	5.9	11.4	15.5	17.7	19.0

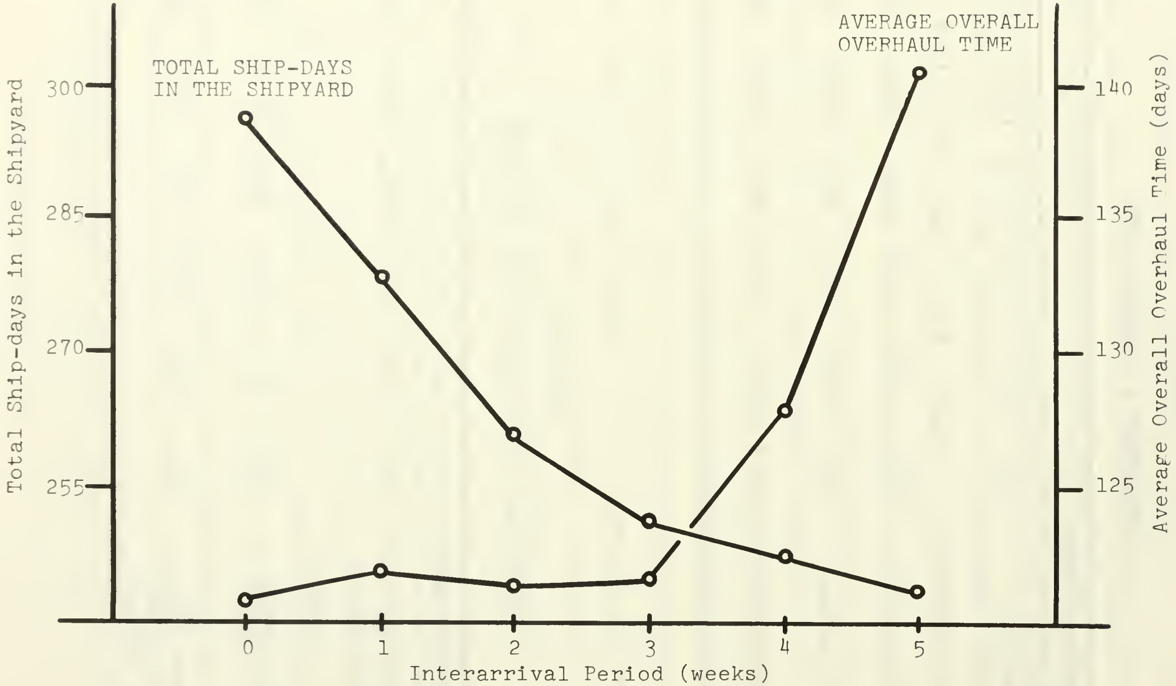


Figure 9. Overall Overhaul Time and Total Ship-Days in the Shipyard vs. Interarrival Period

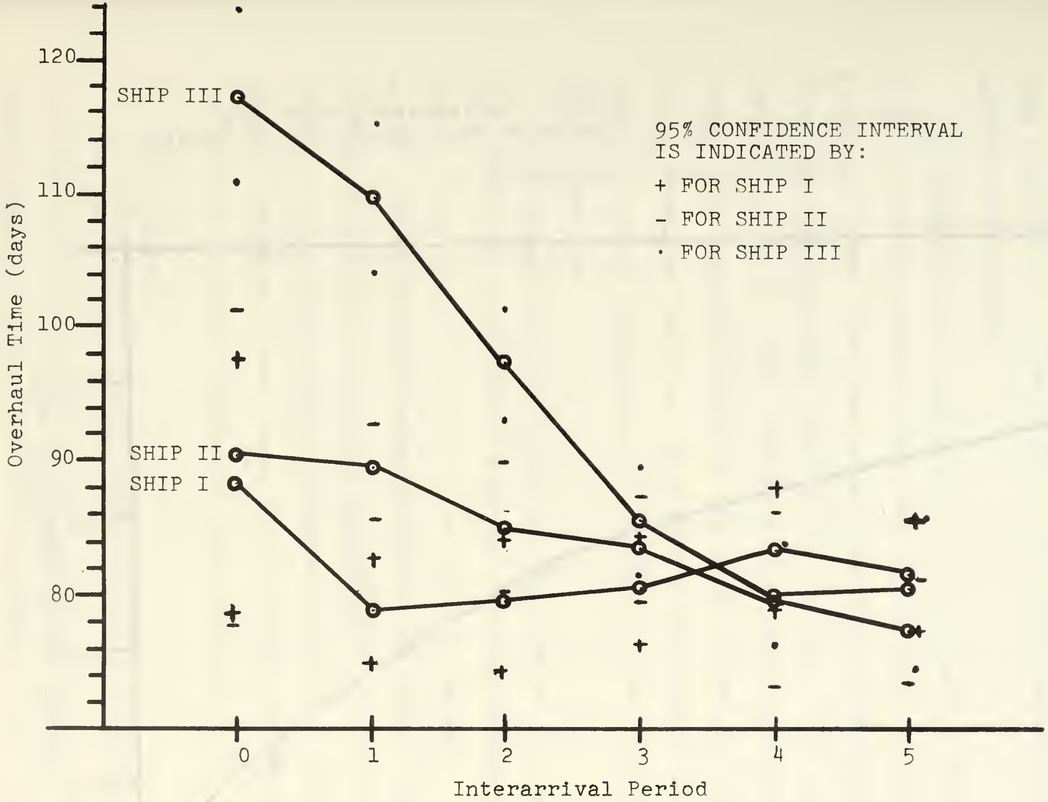


Figure 10. Individual Ship Completion Time vs. Interarrival Period

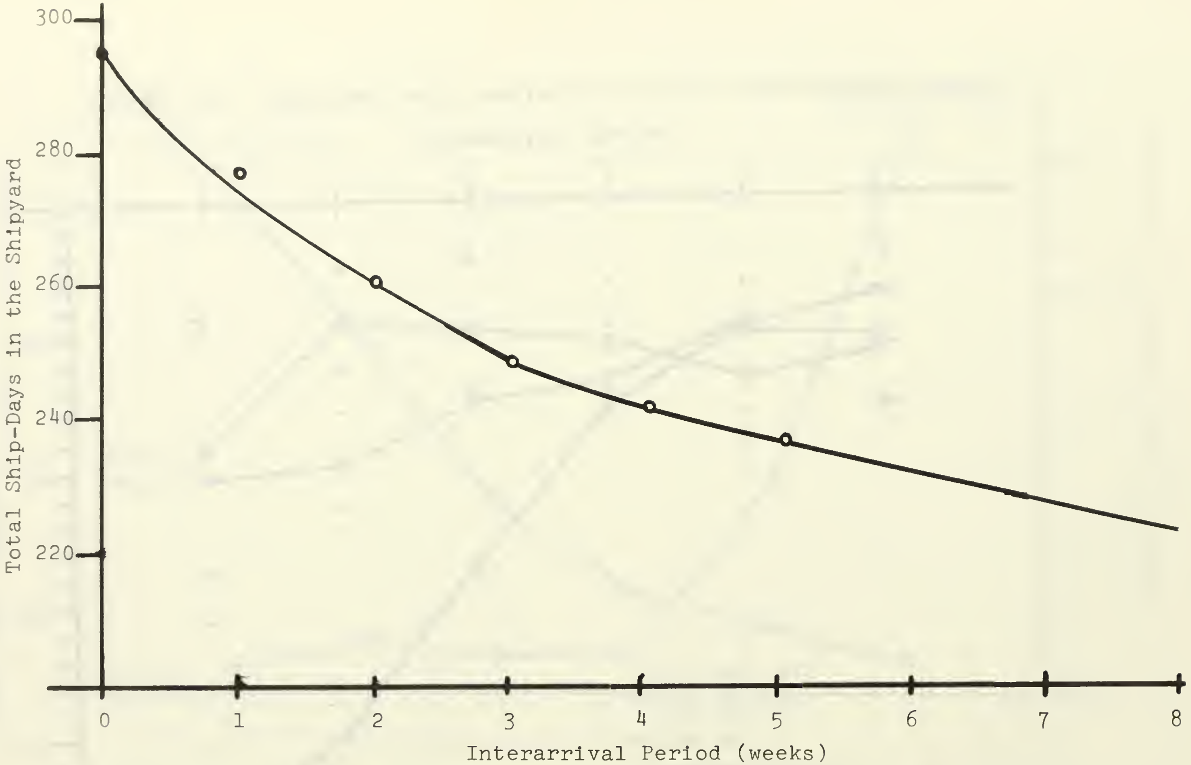


Figure 11. Determination of Asymptotic Number of Ship-Days in the Shipyard for Large Interarrival Periods

in the single ship model as discussed in Section IV,E,3 because the personnel resources available were increased in the triple ship model. However, with increasingly larger interarrival periods, this time should approach the time required to perform a single ship TRAM overhaul with unlimited resources.

An analysis of the time required to accomplish Phase I work in both the two and three week interarrival period scenarios showed that there were significant differences among the overhaul times for the three ships. This can be seen in Figure 12. This indicates that there is a strong interaction among the ships in the Phase I work for these two interarrival periods. This strong interaction did not appear to exist in the case of the four or five week interarrival periods.

With the exception of Phase II, ship one of the two and the three week interarrival periods, a corresponding analysis of Phase II and Phase III work did not indicate significant differences among ships for any other interarrival period or for the same ship between interarrival periods. This can be seen in Figures 13 and 14. This suggests that the Phase I work is the primary contributor to the differences in individual ship overhaul times.

D. EXPERIMENT B

The availability of personnel resources to accomplish the work at each activity in the project network significantly affects the time required to complete that activity

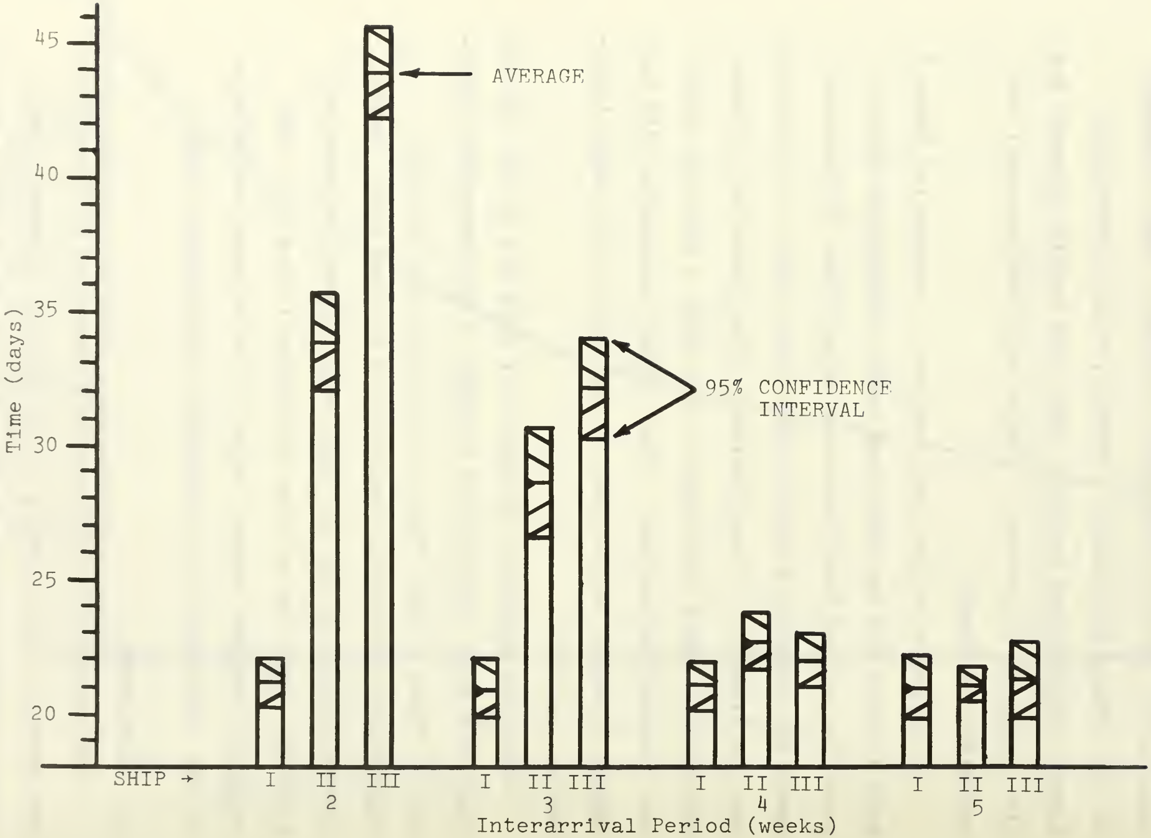


Figure 12. Experiment A, Phase I Completion Time vs. Interarrival Period

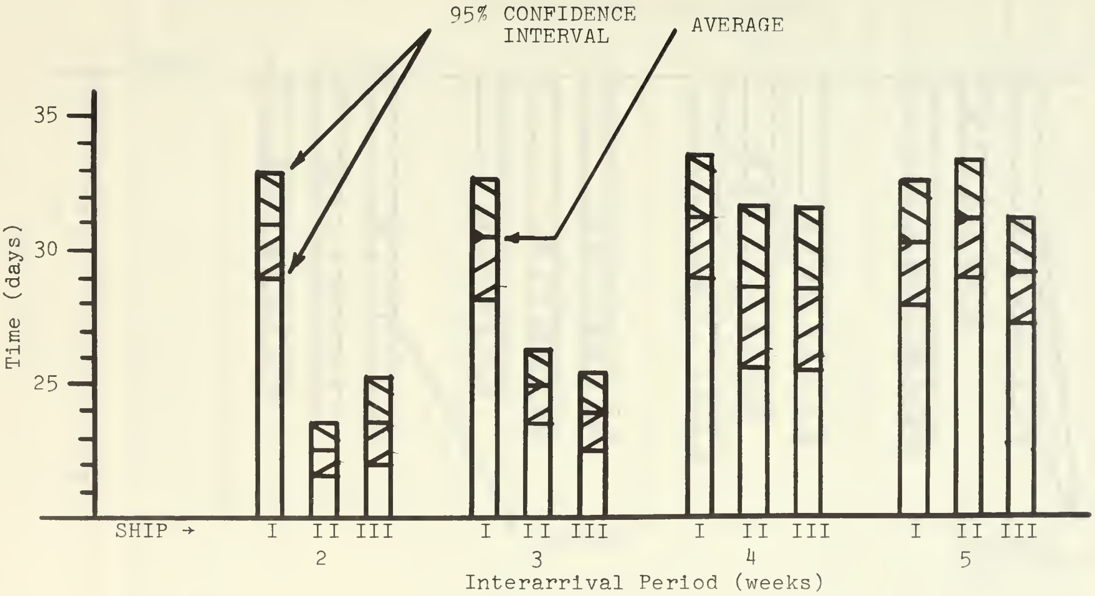


Figure 13. Experiment A, Phase II Completion Time vs. Interarrival Period

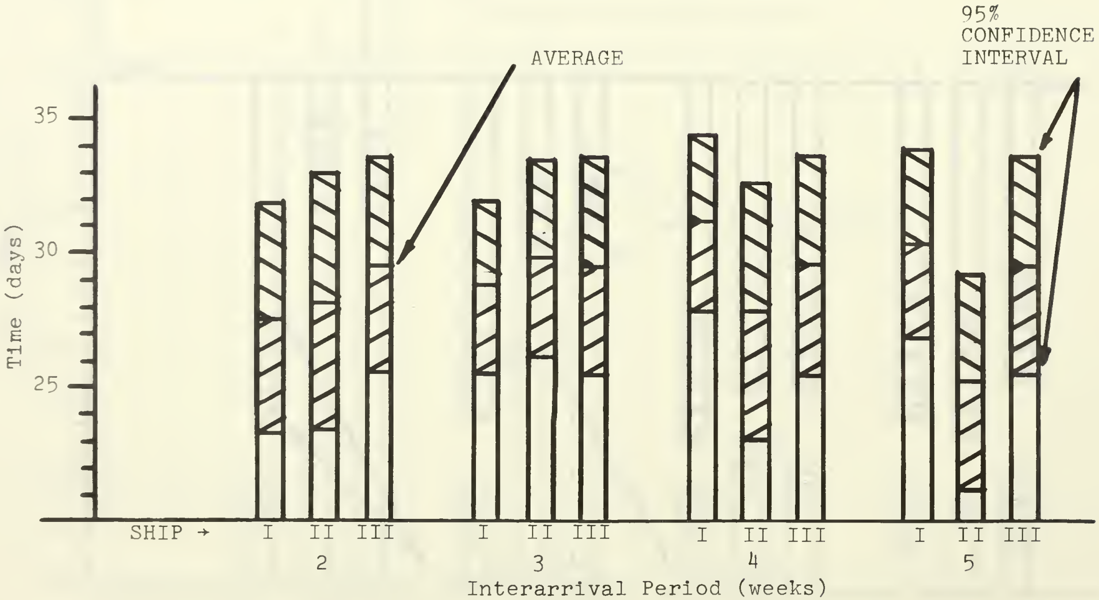


Figure 14. Experiment A, Phase III Completion Time vs. Interarrival Period

and possibly the time required to complete the project. Restrictions on personnel resources are described in Section IV,C,5. The minimum, maximum, and mean overhaul times for these limiting situations in the single ship model were listed in Section IV,E,4. Similarly, a reduction in the time required to complete the triple ship TRAM overhaul can be expected if the number of personnel were to be increased in the work centers which are occasionally depleted or fully utilized.

Since the Long Beach Naval Shipyard had chosen to introduce ships for the TRAM overhaul at two week intervals, this interarrival period was established as the reference scenario. Output reports for the simulation run of the reference scenario indicated that the resources in the following manpower pools were completely depleted the number of times indicated during a ten iteration run:

Shop/Work Center		Times Depleted
17	02	30
51	03	38
51	20	29
67	13	43

Consequently, in Experiment B it was decided to determine the time required to perform an overhaul if each of the above shop/work center pools were increased to a new level which the shipyard environment might reasonably permit. The amount of resources was modified as follows:

Shop/Work Center		Increase	New Quantity
17	02	2	5
51	03	5	23
51	20	8	44
67	13	6	26

With the increased personnel resources, the overall completion time decreased from 121.3 to 108.6 days. The overall and individual ship completion times are tabulated in Table VI and displayed graphically in Figure 15. Also, there was a decrease in the total ship-days in the shipyard. This reduction from 261.9 days in the reference scenario to 247.4 days with the increased manning constitutes a decrease of 5.5% as shown in Table VII. The resource utilization for the two scenarios is shown in Table VIII. By increasing the manpower pools, the complete depletion of these resources was virtually eliminated. Consequently, no delays were experienced in the completion of activities because of the unavailability of men in these work centers.

An analysis of the time required to accomplish Phase I work in the reference scenario showed that significant differences existed among the three individual ships. However, in the increased manning scenario the time required by Ships II and III was greater than that required by Ship I, but the time for Ship III was no longer significantly greater than that for Ship II. This can be seen in Figure 16.

TABLE VI

EXPERIMENT B OVERHAUL TIME

Manning Level	Ref.	Increased
Overall Completion Time	121.3	108.6
Ship I Completion Time	79.7	76.1
Ship II Completion Time	84.9	86.7
Ship III Completion Time	97.3	84.6

TABLE VII

EXPERIMENT B SHIP-DAYS IN THE SHIPYARD

Manning Level	Ref.	Increased
Total of Mean for Individual Ships (Ship-days)	261.9	247.4
Average of Mean Time for Three Ships (Days)	87.4	82.5
% Decrease from Normal Manning	0	$\frac{261.9-247.4}{261.9} = 5.5\%$

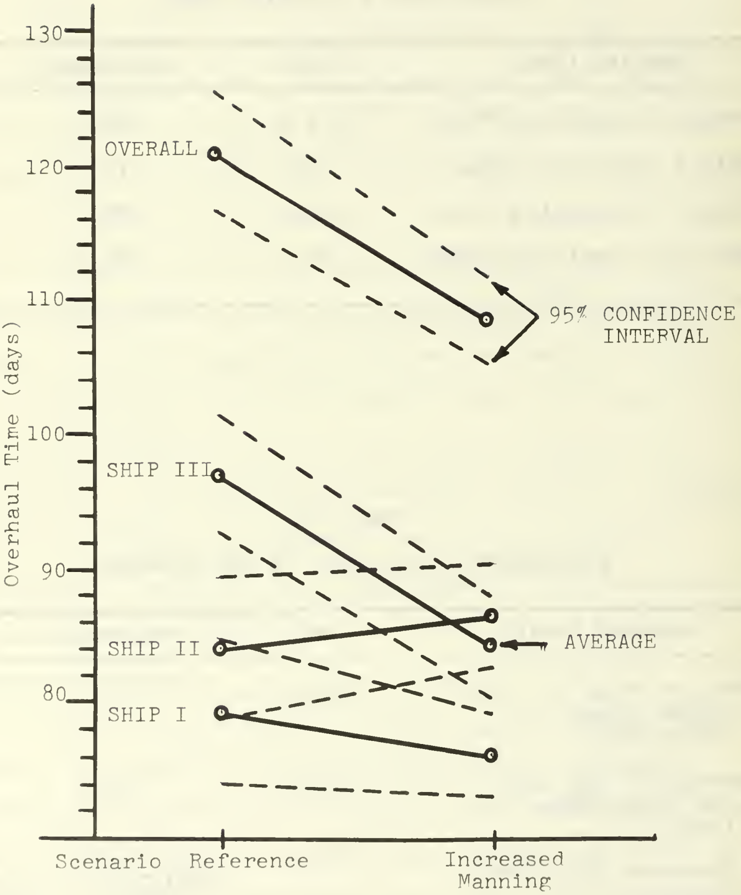


Figure 15. Overall and Individual Ship Overhaul Time vs. Manning

TABLE VIII

PERSONNEL RESOURCE UTILIZATION

		NORMAL RESOURCES			INCREASED RESOURCES		
Shop	W/C	Pool Size	Number Times Depleted[1]	% Time Depleted[2]	Pool Size	Number Times Depleted	% Time Depleted
17	02	3	30	0.9%	5	0	0.0%
15	03	18	38	.3	23	0	.0
51	20	36	29	.1	44	0	.0
67	13	20	43	.4	26	1	.1

[1] Indicates the total number of times during the entire ten iteration run that all personnel available in the associated pool were simultaneously working.

[2] Indicates percent of total time during the ten iteration run that all personnel were simultaneously working.

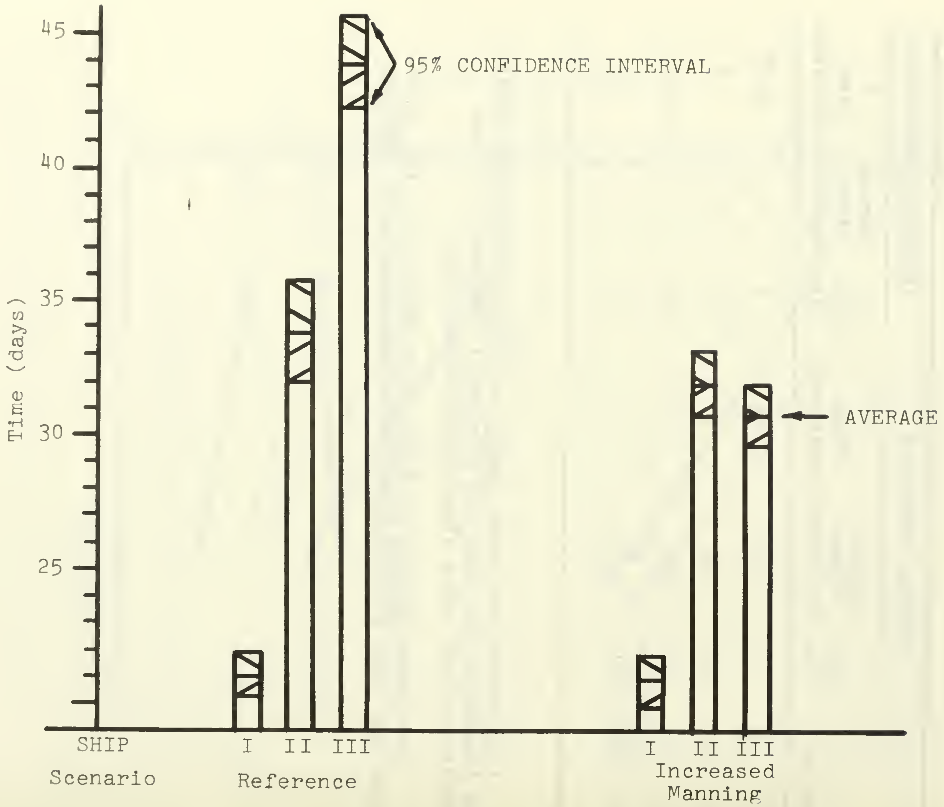


Figure 16. Experiment B, Phase I Completion Time vs. Manning

With the exception of the Phase II work on Ship I in the reference scenario, the times required to accomplish Phases II and III were not significantly different among ships, as can be seen in Figures 17 and 18. Therefore, the reduced interaction among the ships in Phase I appears to be the contributing factor in the reduction of the individual ship overhaul times for the increased manning scenario.

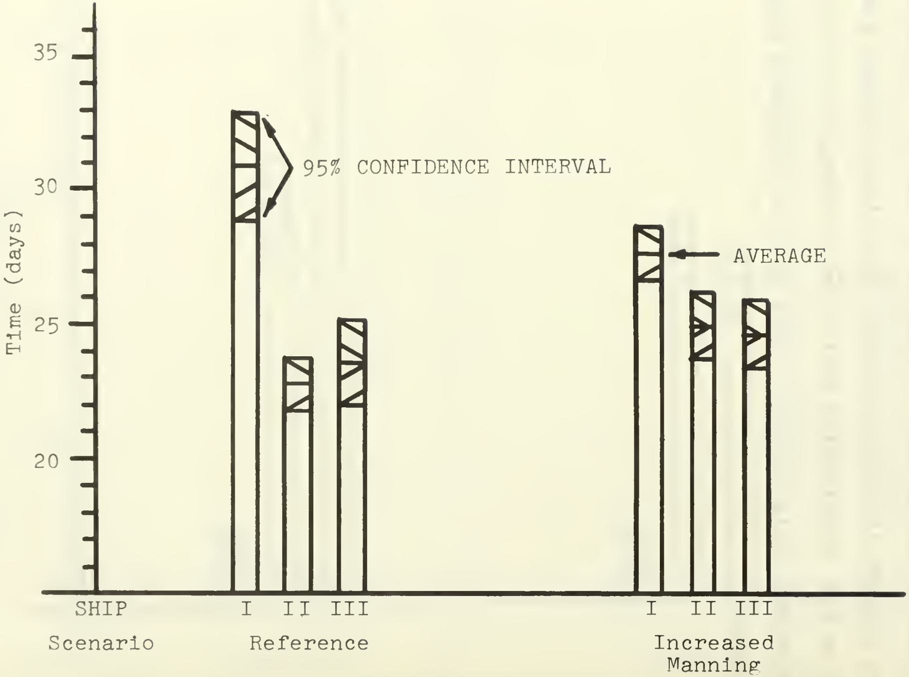


Figure 17. Experiment B, Phase II Completion Time vs. Manning

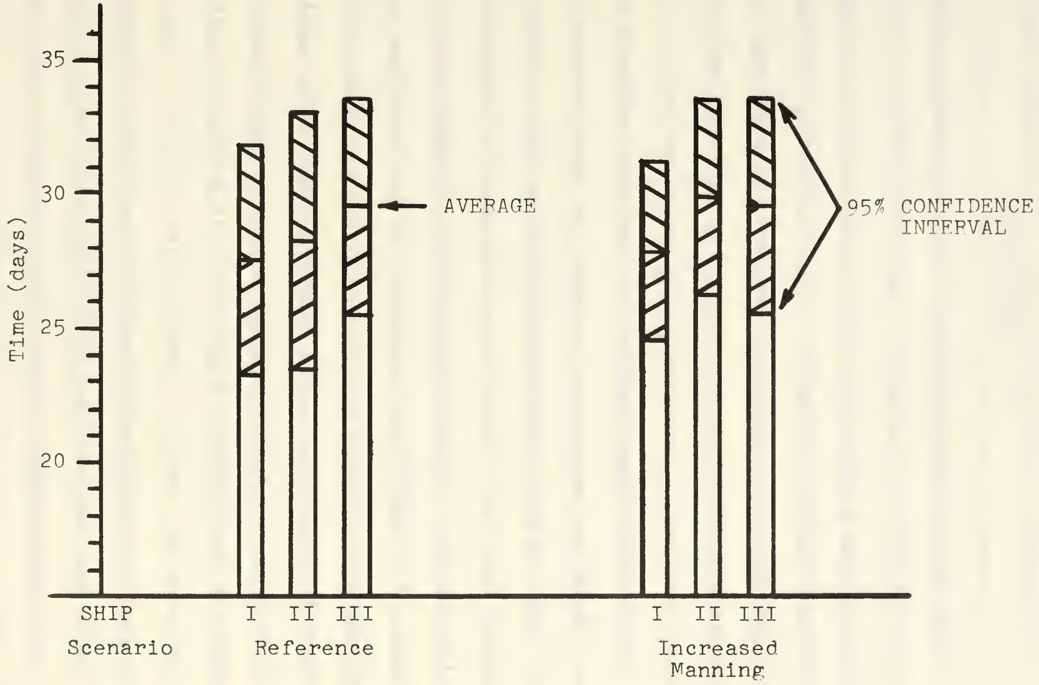


Figure 18. Experiment B, Phase III Completion Time vs. Manning

VI. CONCLUSIONS

This study has investigated several possible alternatives available to management confronted with the problem of completing a triple ship TRAM overhaul with the ships arriving in quick succession. These alternatives have included changes in the ship interarrival periods, investigated in Experiment A, and changes in the available personnel resources, investigated in Experiment B.

The overall time required to complete overhauls on all three ships was consistently about 121 days for the zero, one, two, and three week interarrival periods. This total overhaul time was, therefore, independent of the interarrival period. The strong interaction among ships resulted in significant extensions in the individual ship overhaul times beyond the time required for overhaul without interaction. These extended times were particularly evident with the zero, one, and two week interarrival periods as indicated by Figure 10. It was not possible to decrease the overall overhaul time below 121 days, and there was the undesirable result of delaying individual ships if the interarrival period was three weeks or less.

An investigation of the overall completion time also identified the interarrival period after which strong interaction between the ships ceased to exist and the individual ship overhaul times became independent. The increase of two weeks in the overall completion time between the four and five week interarrival period runs shown in Figure 9 is a result only of the increase in interarrival time and not of any interaction among the ships.

Figure 11 indicates the gradual reduction of the total ship-days in the shipyard with an increasing interarrival period. The asymptotic value of approximately 215 days in the sum of the individual ship overhaul times which stabilize beyond the five week interarrival period.

An experiment was performed which investigated the effect of increasing the personnel resources available while maintaining a two week interarrival period. The overall completion time decreased from 121.3 to 108.6 days. The total ship-days in the shipyard changed from 261.9 to 247.4, a decrease of 5.5%, under the condition of increased resources. With the personnel resource levels of Experiment A this same number of ship-days in the shipyard would be experienced if the interarrival period were about three and one half weeks, as can be seen by interpolating on Figure 9.

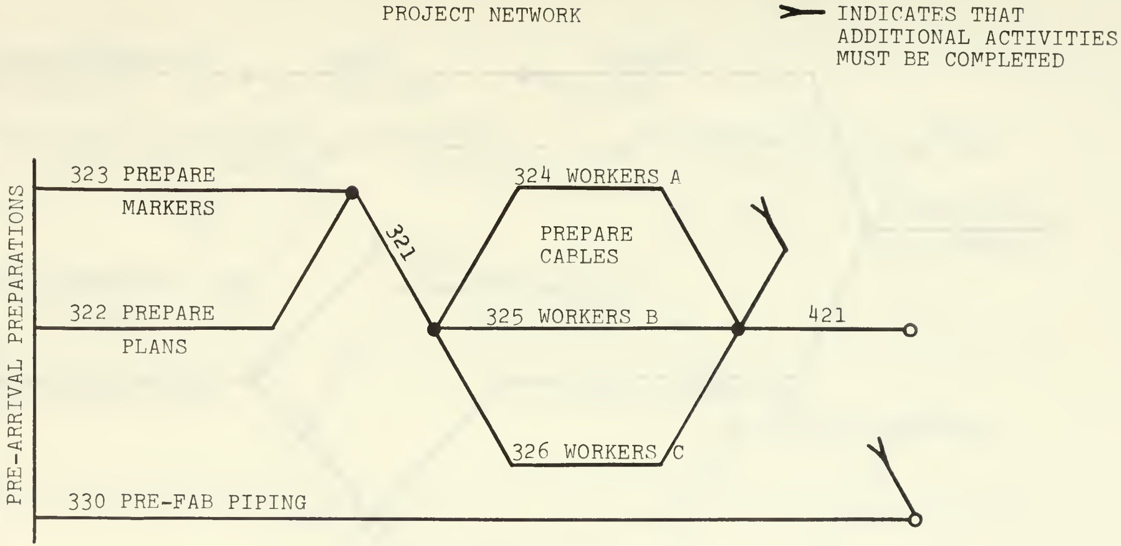
It appears that with the significant reduction in ship interaction with interarrival periods of three weeks and greater, that a three week interarrival period might be desirable. However, if it could be anticipated that personnel resources in some work centers could be increased slightly during critical periods, then a shorter interarrival would be acceptable. In addition, shipyard workmen seem to be most productive when sufficient work is scheduled to insure that their jobs will not be jeopardized by a potential reduction in the labor force. After considering this psychological factor and the possibility of making additional men available temporarily in critical areas, it appears that the original decision by the Long Beach Naval Shipyard to introduce ships for the TRAM overhaul at two week intervals was sound.

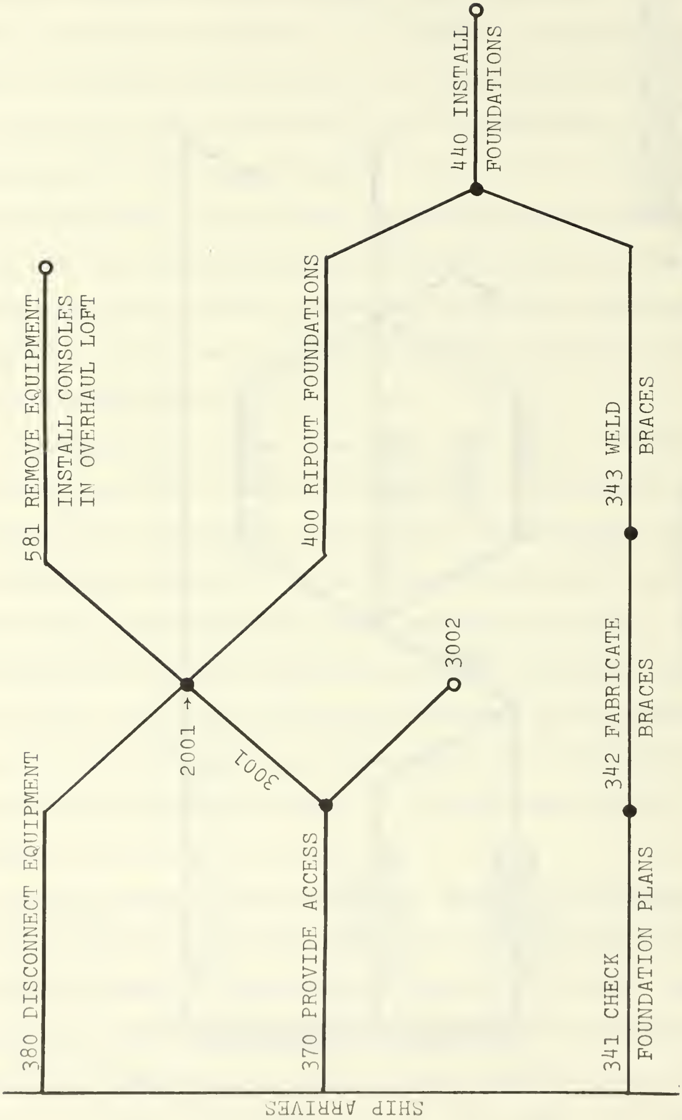
This study has demonstrated the usefulness of computer simulation and the "TRANSIM" simulator for providing management with the capability of evaluating alternatives prior to committing resources. Simulation reduced the uncertainty surrounding these alternatives. However, it did not assess the impact of external administrative action imposed during a project. The effort required to conduct such a study can be justified when either a large number of ships will be exposed to similar treatments or a single ship is to undergo a large and costly project.

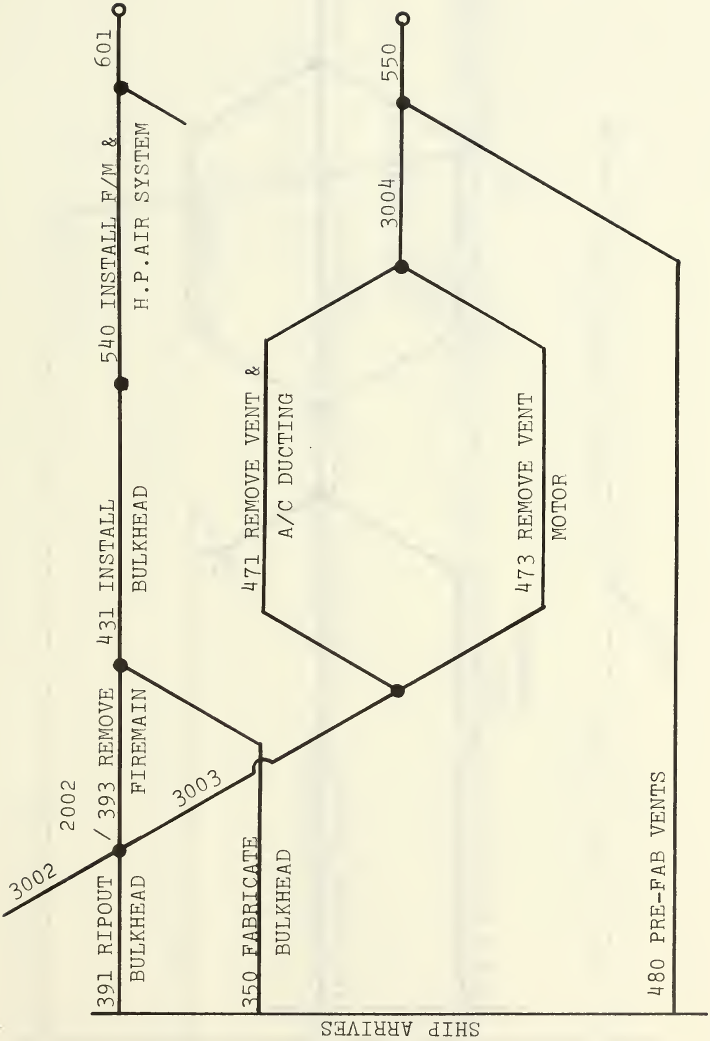
If the current study were to be employed as a managerial tool, an important extension would be to modify the output reports in order to identify critical paths. Other logical extensions might include the investigation of additional scenarios, comparison of the technique employed with other network analysis techniques such as CPM, PERT, the CLARK-BIAS Method (Ref. 4) and the use of alternate simulation systems such as GPSS or SIMSCRIPT.

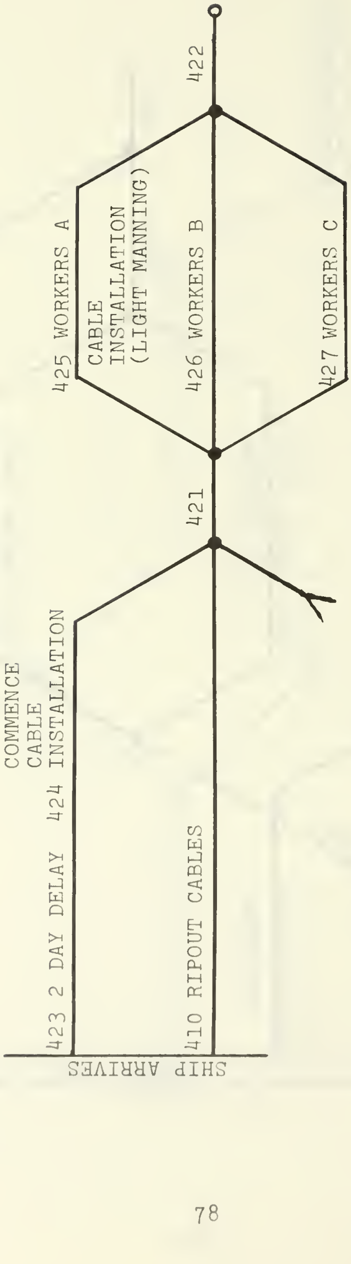
APPENDIX A

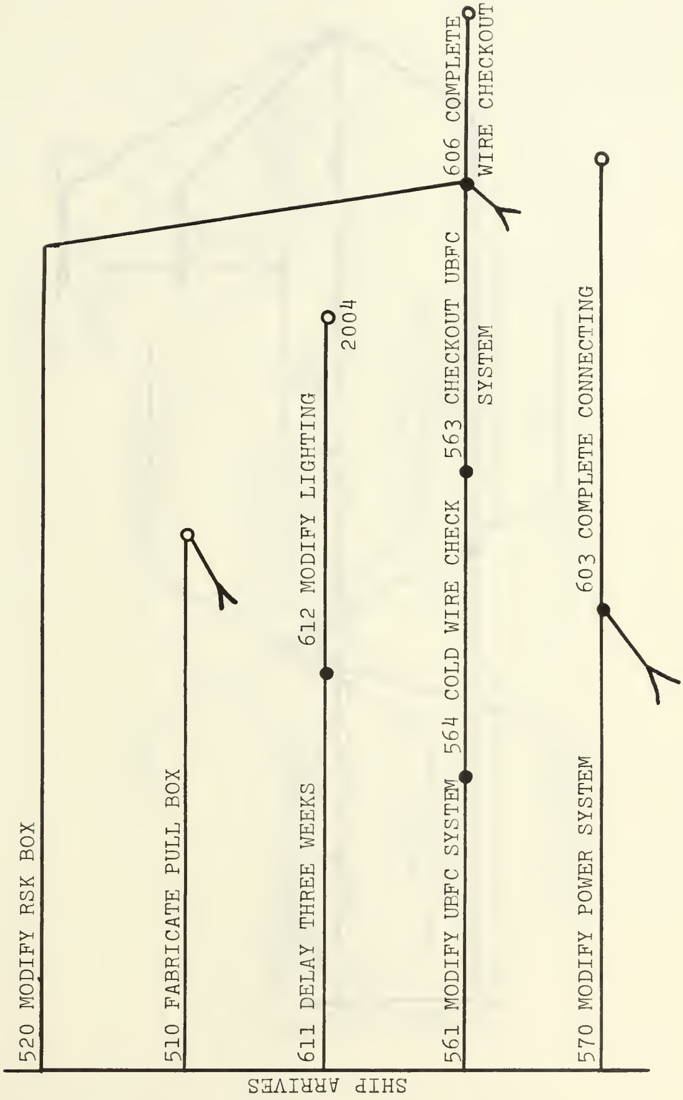
PROJECT NETWORK

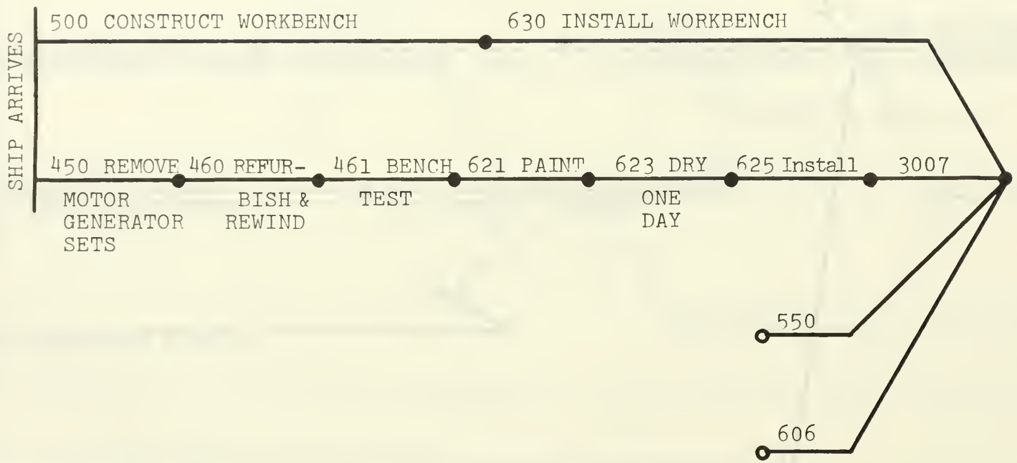


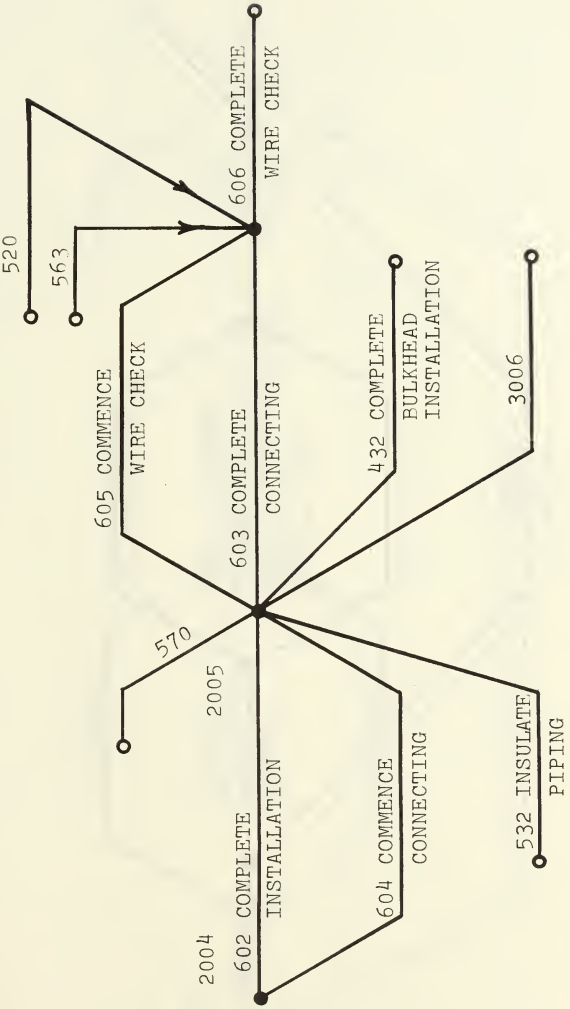

SHIP ARRIVES
380 DISCONNECT EQUIPMENT
581 REMOVE EQUIPMENT
INSTALL CONSOLES
IN OVERHAUL LOFT
2001
3001
3002
370 PROVIDE ACCESS
400 RIPOUT FOUNDATIONS
440 INSTALL
FOUNDATIONS
341 CHECK
FOUNDATION PLANS
342 FABRICATE
BRACES
343 WELD
BRACES

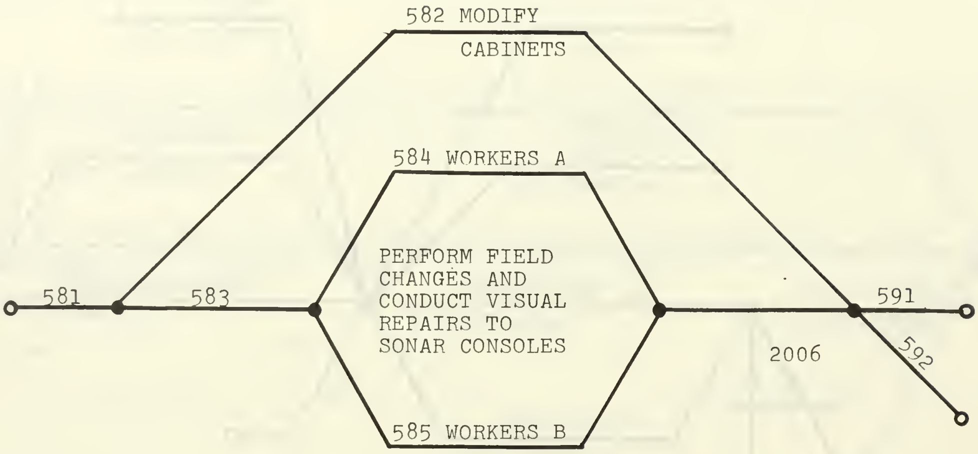

SHIP ARRIVES
391 RIPOUT BULKHEAD
3002
2002
393 REMOVE FIREMAIN
3003
431 INSTALL BULKHEAD
540 INSTALL F/M & H.P.AIR SYSTEM
601
350 FABRICATE BULKHEAD
471 REMOVE VENT & A/C DUCTING
473 REMOVE VENT MOTOR
3004
550
480 PRE-FAB VENTS

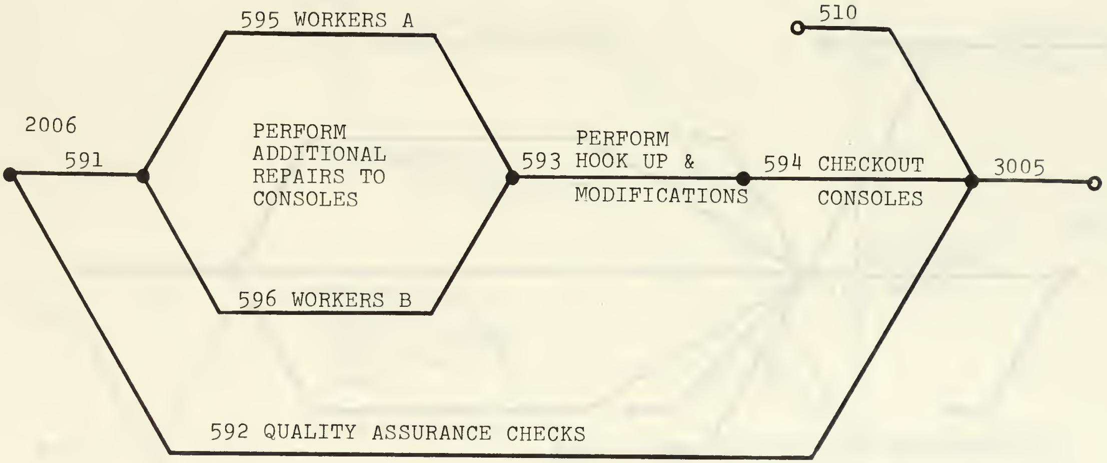

SHIP ARRIVES
410 RIPOUT CABLES
423 2 DAY DELAY
424 COMMENCE CABLE INSTALLATION
421
425 WORKERS A
CABLE INSTALLATION (LIGHT MANNING)
426 WORKERS B
427 WORKERS C
422

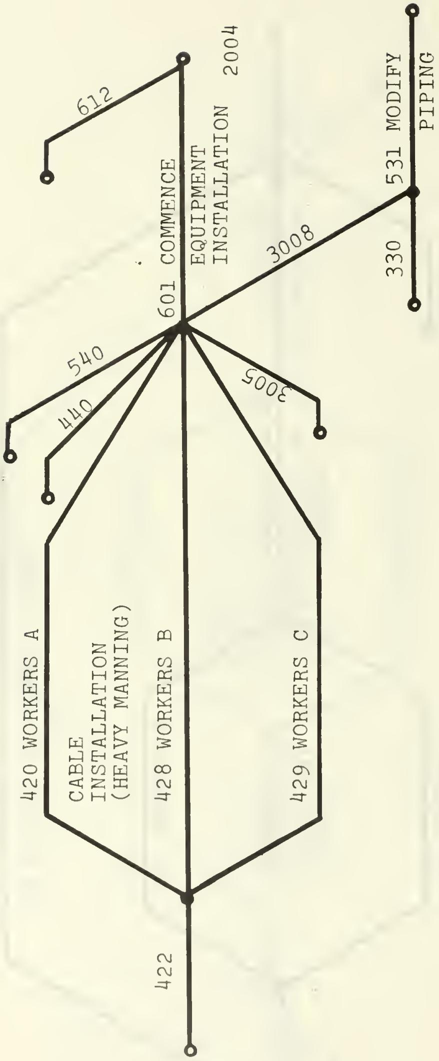

SHIP ARRIVES
520 MODIFY RSK BOX
510 FABRICATE PULL BOX
611 DELAY THREE WEEKS
612 MODIFY LIGHTING
2004
561 MODIFY UBFC SYSTEM
564 COLD WIRE CHECK
563 CHECKOUT UBFC SYSTEM
606 COMPLETE WIRE CHECKOUT
570 MODIFY POWER SYSTEM
603 COMPLETE CONNECTING

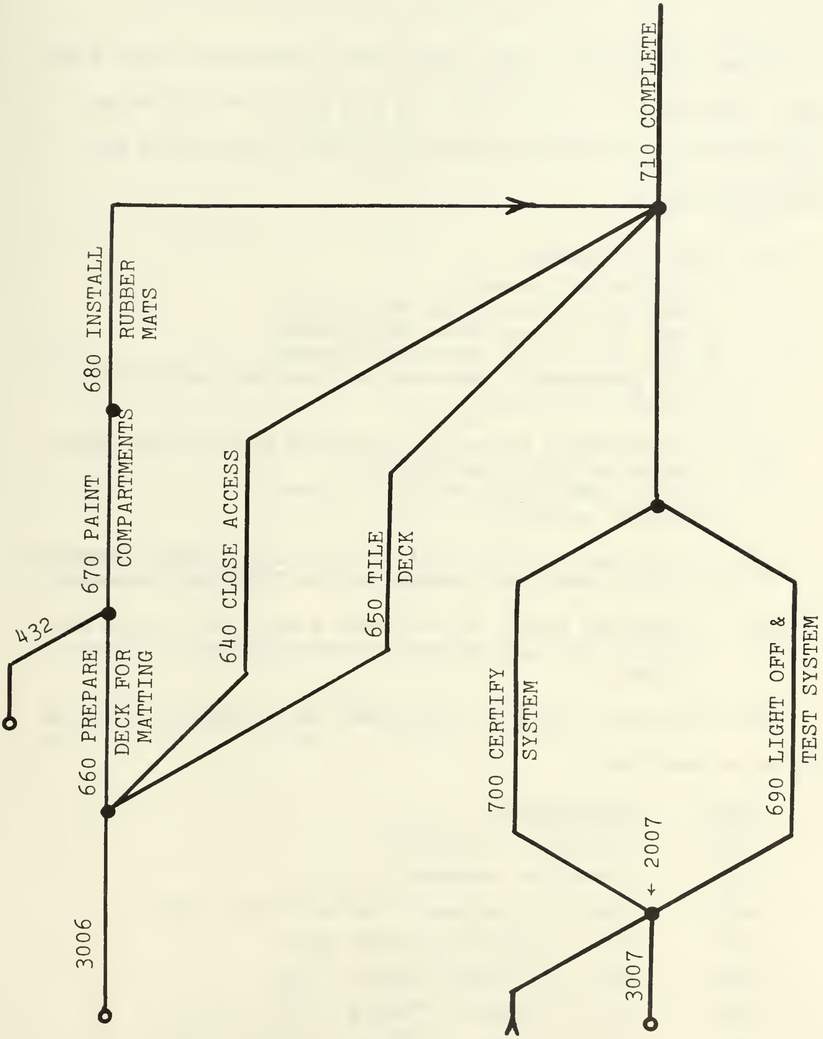

SHIP ARRIVES
500 CONSTRUCT WORKBENCH
630 INSTALL WORKBENCH
450 REMOVE MOTOR GENERATOR SETS
460 REFUR-BISH & REWIND
461 BENCH TEST
621 PAINT
623 DRY ONE DAY
625 Install
3007
550
606


2004
602 COMPLETE INSTALLATION
604 COMMENCE CONNECTING
532 INSULATE PIPING
2005
570
605 COMMENCE WIRE CHECK
603 COMPLETE CONNECTING
432 COMPLETE BULKHEAD INSTALLATION
3006
520
563
606 COMPLETE WIRE CHECK


582 MODIFY
CABINETS
584 WORKERS A
PERFORM FIELD
CHANGES AND
CONDUCT VISUAL
REPAIRS TO
SONAR CONSOLES
585 WORKERS B
581
583
2006
591
592


595 WORKERS A
510
2006
591
PERFORM ADDITIONAL REPAIRS TO CONSOLES
593 PERFORM HOOK UP & MODIFICATIONS
594 CHECKOUT CONSOLES
3005
596 WORKERS B
592 QUALITY ASSURANCE CHECKS


612
2004
601 COMMENCE EQUIPMENT INSTALLATION
3008
531 MODIFY PIPING
330
540
440
3005
420 WORKERS A
CABLE INSTALLATION (HEAVY MANNING)
428 WORKERS B
429 WORKERS C
422


3006
660 PREPARE DECK FOR MATTING
432
670 PAINT COMPARTMENTS
680 INSTALL RUBBER MATS
640 CLOSE ACCESS
650 TILE DECK
710 COMPLETE
3007
← 2007
700 CERTIFY SYSTEM
690 LIGHT OFF & TEST SYSTEM

APPENDIX B

TRAFFIC UNIT TYPE NUMBERING CONVENTIONS

Given any traffic unit type whose numerical value has been converted to five digits, A B C D E, the following conventions have been employed in their application and interpretation:

A: The ship number

- 0 single ship model
- 1 ship #1 of the three ship model
- 2 ship #2 of the three ship model
- 3 ship #3 of the three ship model
- 4 all personnel resources or manpower pools (see exceptions below)

B:
- 2 Convergence nodes for multiple activities generating multiple activities
- 3 Zero time delay activity lines
- 5 Manned activity

C D: A two digit number indicating the shipyard assigned "key operation" number in the TRAM work request

E: A refining digit to indicate a specific evolution within the key operation established by digits C and D.

The following traffic unit types are exceptions to the above conventions:

TYPE	DESCRIPTION
710	Iteration "starter"
999	Iteration counter
90000	Overall Overhaul Timing Traffic Unit
10000	Ship I Timing Traffic Unit
20000	Ship II Timing Traffic Unit
19001	Ship I Phase I Timing Traffic Unit
19002	Ship I Phase II Timing Traffic Unit
39001	Ship III Phase I Timing Traffic Unit, etc.

If digit A is a 4, then digits B and C identify the shop, and digits D and E identify the work center.

APPENDIX C

DESCRIPTION OF THE NATURE OF WORK PERFORMED BY WORK CENTERS

Shipfitter Shop (X11)

Work Center	No.	Work Description
Loft	01	Make templates from plans. Prepare bill of material, sketches and templates. Break down fabrications into assemblies. Lay out body lines on loft floor from plans.
Assembly and Watertight	04	Make layout for assembly. Manufacture and set up jigs. Assemble per plan and templates. Fit up and make ready for production welding. Clean surfaces to be welded. Repair items delivered from ship. Strip off deteriorated rubber and clean exposed surfaces. Inspect and repair panels. Repair, modify or renew parts of doors, hatches, scuttles, and air ports. Install new rubber and gaskets.
Pneumatics (Field)	05	Perform the following operations: drill, drill and tap, drill and countersink, ream for riveting, chip bevels for welding, rivet plates and beams, caulk riveted and welded seams, air and hydrostatic tests, bolt up for riveting, remove and replace tank tops.
Shipfitters (Non-drydock)	06	Remove, repair, modify or renew, and reinstall structural fittings and components of hull.

Sheetmetal Shop (X17)

Work Center	No.	Work Description
Sketching and Layout	01	Investigate jobs aboard ship. Determine specific manufacturing and installation requirements.

Machine	02	Perform heavy machine work necessary in sheetmetal manufacture - forming, nibbling, notching, punching, sawing, spot welding. On large jobs - drilling, tapping, counter-sinking. Dip clean aluminum. Fabricate spools and all flanges, round, flat, oval, rectangular and square.
Manufacturing	03	Fabricate and assemble the following: bulkheads, electrical equipment, furniture, ladders, messing and berthing equipment, partitions, racks and stages, refrigeration space equipment, shelving and bin stowage, stainless steel equipment, work benches, miscellaneous (guards, boxes, brackets, enclosures, trays, etc.)
Ventilation	04	Fabricate, form and assemble the following: watertight and non-watertight ducting, fittings and associated items, ventilation hoods, spools, screens, covers, etc. as required for shipboard ventilation, heating, and air conditioning.
Sheetmetal Field	05	Accomplish all outside work including removal, installation and job site repairs.

Welding Shop (X26)

Work Center	No.	Work Description
Welders - (Inside Shop 11)	01	In conjunction with inside shop ship-fitters work, perform: manual electric, submerged arc, steel build-up, aircromatic, heliarc, and machine (carriage) welding; hand and machine burning and carbon arc burning.
Welders - Field	05	Perform all welding and burning operations aboard ship. Spray protective coatings. Stud weld zincs and insulation pins. Stress relieve piping.

Inside Machine Shop (X31)

Work Center	No.	Work Description
Electric	07	Repair electric motor components (examples): (a) Dynamic balancing of all types of electrical rotating elements (b) Metal spray motor end bell bearing areas (c) Manufacture of switchboard compartments (d) Stone slip rings and turn commutators in place and in shop (e) Overhaul, repair, and assemble magnetic clutches
Weapons Mechanical and Weapons Hydraulic (Ship)	07	Perform shipboard removal, installation, overhaul, repair, modification and test of gun mounts, directors, missile and rocket launchers, projectors, torpedo mounts, loaders, hoists, power drivers and optical equipment. Assist Work Center 11 in the removal and reinstallation and check out of all receiving, indicating and regulating devices. Compile cam-plot data, scribe blanks, repair, install, align, and checkout mechanical components and linkage related to firing cut-off cams and interrupters. Install and check out all missile launcher control and firing cams. Conduct mechanical leveling, aligning, drilling, bolting and unbolting services for sonar transducers and domes, pelorus stands, master gyro compasses, motor-generator sets, and electrical and electronic units requiring mechanical leveling and alignment.
Weapons Systems, ASW and Fire Control General (Ship)	10	Remove, install, field repair, modify, assemble, and ship test electrical electro-mechanical, and electronic components of missile control, computing and guidance systems, missile and fire control radar and radar components

		installed on gun mounts. Conduct integrated checkout of weapons and fire control system including associated or related switchboard assemblies. Insure that missile and fire control inputs and orders of proper magnitude, phase, and direction are provided to associated receiving, indicating, and regulating devices including sonar and launcher systems. Remove, install, field repair and modify components of underwater battery fire control systems.

Electric Shop (X51)

Work Center	No.	Work Description
Motors	01	Perform shop repair of motors, generators and motor generators, starters and generators.
Switchboard	03	Perform shop repair of controllers, panels, resistor banks, navigational lights, appliances, telephone switchboards, transfer switches, circuit breakers, galley equipment, and light fixtures.
Test	08	Conduct pre and post test of motor generators. Post test all shop repaired electrical equipment. Repair and test all voltage regulators.
Gyro	11	Inspect and repair master gyro compass and associated equipment
Field - Electrical	20	Install all electric plant, cabling, control devices and power consuming devices, including electronic installations and new weapons systems installations. This includes the functions of layout, non-structural drilling, bolting up, bonding, stud welding, cabling connecting and wire checking. Accomplish the same functions in connection with the removal and

ripout operations. Conduct visual and operational checks of electric plant installation and equipments not specifically assigned to other work centers.

Pipefitter Shop (X56)

Work Center	No.	Work Description
Laggers - Field	05	Remove, replace, renew and install insulation for piping systems, machinery, ventilation, refrigeration and air conditioning equipment. Repair damage and miscellaneous lagging requirements by ship.
Pipefitters - Field	06	Remove, replace, repair, renew and install all piping systems.

Woodworking Shop (X64)

Work Center	No.	Work Description
Shipwright and Joiner - Field	06	Build, repair and alter all wooden items aboard ship. Install insulation, linoleum and safety walks. Provide, erect and remove wooden tubular staging. Lay wooden decking and machinery foundations. Insert wood caulking on decks and hulls. Establish all working lines. Perform all wood work associated with boat stowage, drydocking, layout and shoring. Install reinforced plastic radome, water rheostat tanks, etc.

Electronics Shop (X67)

Work Center	No.	Work Description
Sonar and Fathometer Equipment and Systems	13	Repair, modify, calibrate, and test sonar and fathometer equipment. Disconnect and reconnect sonar transducers.

Paint Shop (X71)

Work Center	No.	Work Description
Shop Painters	02	Operate paint booths in shops. Stripe and paint hard hats. Operate varnish and sign shops.
Tilesetters	03	Install Terrazo magnesite, ceramic tile, cement and deck fairing work.
Topside Painters	04	Perform compartment painting, all exterior painting above water-line, masking and touch-up work.

Rigging Shop (X72)

Work Center	No.	Work Description
Laborers	02	Prepare surface for paint, tile, and Terrazzo. Clean ship. Remove sand from dock basin and wash down. Provide janitorial services.
Ship Riggers	05	Disassemble, assemble, remove and replace all ships' machinery and equipment. Provide docking and undocking services, operate boats and floating cranes and provide yard security.

Code	Title
135	Quality Assurance Inspectors
290	Combat Systems Inspectors

APPENDIX D

DETERMINATION OF CONFIDENCE INTERVALS

The following calculation demonstrates the use of the Student T distribution to determine a confidence interval of the mean for Phase I, Ship I in the two week normal manning scenario with a sample size of ten:

$\overline{X} = 21.1$ days

$S_X = 1.3$ days

$S_{\overline{X}} = \frac{1.3}{\sqrt{n}} = \frac{1.3}{\sqrt{10}} = .42$ days

Degrees of Freedom = 10 - 1 = 9

From a table of the Student T distribution:

$$t_{.975_{(9)}} = 2.262$$

Therefore, the confidence interval of the mean can be stated in terms of a probability as follows:

$$P[\overline{X} - t_{.975_{(9)}}(S_{\overline{X}}) \leq \mu \leq \overline{X} + t_{.975_{(9)}}(S_{\overline{X}})] = .95$$

$$P[\{21.1 - 2.262(.42)\} \leq \mu \leq \{21.1 + 2.262(.42)\}] = .95$$

$$P[20.15 \leq \mu \leq 22.05] = .95$$

The following calculation demonstrates the use of the Student T distribution to determine if means are equal at a .05 level of significance. Although this method was not used in the analysis, the technique is demonstrated in the following comparison between the overall overhaul times in Experiment B and could be applied to other situations if desired:

R = Reference Scenario

I = Increased Manning Scenario

$n_1 = n_2 = 10$

$\overline{X}_R = 121.3$ days

$\overline{X}_I = 108.6$ days

$|\overline{X}_R - \overline{X}_I| = 12.7$ days

$S_R = 5.9$ days

$S_I = 4.4$ days

$t^* = t_{1-\frac{\alpha}{2}\,(n_1+n_2-2)} = t_{.975(18)} = 2.101$

The interval of acceptance is given by the following probability statement:

$$P\left(-t^* \sqrt{\frac{S_R^{\,2}}{n_1} + \frac{S_I^{\,2}}{n_2}} \leq (\overline{X}_R - \overline{X}_I) \leq t^* \sqrt{\frac{S_R^{\,2}}{n_1} + \frac{S_I^{\,2}}{n_2}}\right) = .95$$

$$P\left(-2.101 \sqrt{\frac{(5.9)^2}{10} + \frac{(4.4)^2}{10}} \leq (\overline{X}_R - \overline{X}_I) \leq + 2.101\sqrt{\frac{(5.9)^2}{10} + \frac{(4.4)^2}{10}}\right) = .95$$

$$P\left(-4.88 \leq (\overline{X}_R - \overline{X}_I) \leq 4.88\right) = .95$$

Since $\overline{X}_R - \overline{X}_I$ is outside the above interval, the hypothesis that the means are equal is rejected with a confidence level of 95%.

APPENDIX E

MEAN AND STANDARD DEVIATION FOR OVERHAUL TIMES

EXPERIMENT A

Interarrival Period (weeks)	Work Segment		Average	Standard Deviation
0	Overall		120.7	4.4
0	Ship I		88.3	13.4
0	Ship II		90.2	14.4
0	Ship III		117.2	9.0
1	Overall		121.9	7.7
1	Ship I		78.9	5.5
1	Ship II		89.5	5.0
1	Ship III		109.9	7.7
2	Overall		121.3	5.9
2	Ship I		79.7	6.9
2	Ship I	Phase I	21.1	1.3
2	Ship I	Phase II	30.9	2.8
2	Ship I	Phase III	27.6	6.0
2	Ship II		84.9	7.1
2	Ship II	Phase I	33.8	2.7
2	Ship II	Phase II	22.7	1.5
2	Ship II	Phase III	28.2	6.7
2	Ship III		97.3	5.9
2	Ship III	Phase I	43.9	2.2
2	Ship III	Phase II	23.6	2.3
2	Ship III	Phase III	29.5	5.8
3	Overall		121.6	5.7
3	Ship I		80.4	5.7
3	Ship I	Phase I	20.9	1.6
3	Ship I	Phase II	30.4	3.3
3	Ship I	Phase III	28.8	4.6

3	Ship II		83.4	5.7
3	Ship II	Phase I	28.6	3.0
3	Ship II	Phase II	24.9	2.0
3	Ship II	Phase III	29.8	5.0
3	Ship III		85.6	5.7
3	Ship III	Phase I	32.1	2.5
3	Ship III	Phase II	23.9	2.1
3	Ship III	Phase III	29.5	5.8
4	Overall		127.9	5.0
4	Ship I		83.5	6.5
4	Ship I	Phase I	21.0	1.3
4	Ship I	Phase II	31.2	3.3
4	Ship I	Phase III	31.1	4.6
4	Ship II		79.5	9.0
4	Ship II	Phase I	22.6	1.7
4	Ship II	Phase II	28.6	4.2
4	Ship II	Phase III	27.8	6.8
4	Ship III		79.9	5.0
4	Ship III	Phase I	21.9	1.4
4	Ship III	Phase II	28.5	4.3
4	Ship III	Phase III	29.5	5.8
5	Overall		140.4	8.0
5	Ship I		81.5	5.4
5	Ship I	Phase I	20.9	1.7
5	Ship I	Phase II	30.2	3.3
5	Ship I	Phase III	30.3	4.9
5	Ship II		77.3	5.4
5	Ship II	Phase I	21.0	1.0
5	Ship II	Phase II	31.1	3.1
5	Ship II	Phase III	25.2	5.6
5	Ship III		80.1	7.6
5	Ship III	Phase I	21.2	2.0
5	Ship III	Phase II	29.2	2.6
5	Ship III	Phase III	29.5	5.8

EXPERIMENT B

Scenario	Work Segment		Average	Standard Deviation
Reference	Overall		121.3	5.9
Reference	Ship I		79.7	6.9
Reference	Ship I	Phase I	21.1	1.3
Reference	Ship I	Phase II	30.9	2.8
Reference	Ship I	Phase III	27.6	6.0
Reference	Ship II		84.9	7.1
Reference	Ship II	Phase I	33.8	2.7
Reference	Ship II	Phase II	22.7	1.5
Reference	Ship II	Phase III	28.2	6.7
Reference	Ship III		97.3	5.9
Reference	Ship III	Phase I	43.9	2.2
Reference	Ship III	Phase II	23.6	2.3
Reference	Ship III	Phase III	29.5	5.8
Increased Manning	Overall		108.6	4.4
Increased Manning	Ship I		76.1	5.5
Increased Manning	Ship I	Phase I	20.8	1.3
Increased Manning	Ship I	Phase II	27.6	1.6
Increased Manning	Ship I	Phase III	27.8	4.7
Increased Manning	Ship II		31.9	1.8
Increased Manning	Ship II	Phase I	24.8	1.2
Increased Manning	Ship II	Phase II	29.8	5.2
Increased Manning	Ship II	Phase III	29.8	5.2

Increased Manning	Ship III		84.6	4.4
Increased Manning	Ship III	Phase I	30.6	1.8
Increased Manning	Ship III	Phase II	24.5	1.8
Increased Manning	Ship III	Phase III	29.5	5.8

APPENDIX F

DESCRIPTION OF ACTIVITIES

Activity	Description
322	PREPARE PLANS FOR CABLE INSTALLATION
323	PREPARE CABLE MARKERS
324	PREPARE CABLES (WORKERS A)
325	PREPARE CABLES (WORKERS B)
326	PREPARE CABLES (WORKERS C)
330	PRE-FABRICATE PIPING
341	CHECK FOUNDATION PLANS
342	FABRICATE BRACES
343	WELD BRACES
350	FABRICATE BULKHEAD
370	PROVIDE ACCESSES
380	DISCONNECT CONSOLES
391	RIPOUT BULKHEAD
393	REMOVE FIREMAIN
400	RIPOUT FOUNDATIONS
410	RIPOUT CABLES
420	HEAVY MANNING CABLE INSTALLATION (WORKERS A)
423	DELAY PRIOR TO COMMENCING CABLE INSTALLATION
424	COMMENCE CABLE INSTALLATION
425	LIGHT MANNING CABLE INSTALLATION (WORKERS A)
426	LIGHT MANNING CABLE INSTALLATION (WORKERS B)
427	LIGHT MANNING CABLE INSTALLATION (WORKERS C)
428	HEAVY MANNING CABLE INSTALLATION (WORKERS B)
429	HEAVY MANNING CABLE INSTALLATION (WORKERS C)
431	INSTALL BULKHEAD
432	COMPLETE BULKHEAD INSTALLATION
440	INSTALL FOUNDATIONS
450	REMOVE MOTOR GENERATOR SETS FROM SHIP
460	REFURBISH AND REWIND MOTOR GENERATOR SETS
461	BENCH TEST MOTOR GENERATOR SETS
471	REMOVE VENTILLATION AND AIR CONDITIONING DUCTING
473	REMOVE VENTILLATION MOTOR
480	PRE-FABRICATE VENTILLATION DUCTING
500	CONSTRUCT WORKBENCH
510	FABRICATE PULL BOX
520	MODIFY RSK BOX
531	MODIFY PIPING
532	INSULATE PIPING
540	INSTALL FIREMAIN AND HIGH PRESSURE AIR SYSTEMS
550	INSTALL VENTILLATION AND AIR CONDITIONING DUCTING
561	MODIFY UNDERWATER BATTERY FIRE CONTROL SYSTEM
563	CHECKOUT UBFC SYSTEM
564	COLD WIRE CHECK UBFC SYSTEM
570	MODIFY POWER SYSTEM

581	DISASSEMBLE SONAR CONSOLES AND MOUNT ON BRACKETS IN REPAIR LOFT
582	MODIFY SONAR CONSOLES
584	PERFORM FIELD CHANGES AND VISUAL REPAIRS TO CONSOLES (WORKERS A)
585	PERFORM FIELD CHANGES AND VISUAL REPAIRS TO CONSOLES (WORKERS B)
592	PERFORM QUALITY ASSURANCE CHECKS ON CONSOLES IN LOFT
593	CONNECT AND MODIFY SONAR CONSOLES IN LOFT
594	CHECKOUT SONAR CONSOLES
595	PERFORM ADDITIONAL REPAIRS TO SONAR CONSOLES (WORKERS A)
596	PERFORM ADDITIONAL REPAIRS TO SONAR CONSOLES (WORKERS B)
601	COMMENCE INSTALLING SONAR CONSOLES IN SHIP
602	COMPLETE INSTALLING SONAR CONSOLES IN SHIP
603	COMPLETE CONNECTING SONAR CONSOLES
604	COMMENCE CONNECTING SONAR CONSOLES
605	COMMENCE WIRE CHECK OF SONAR CONSOLES
606	COMPLETE WIRE CHECK OF SONAR CONSOLES
611	DELAY BEFORE COMMENCING MODIFICATION TO LIGHTING
612	MODIFY LIGHTING
621	PAINT MOTOR GENERATOR SETS
623	DELAY TO ALLOW PAINT TO DRY ON MOTOR GENERATOR SETS
625	INSTALL MOTOR GENERATOR SETS
630	INSTALL WORKBENCH
640	CLOSE ACCESSES
650	TILE LIVING COMPARTMENT DECK
660	PREPARE DECK IN SONAR COMPARTMENT FOR MATTING
670	PAINT SONAR COMPARTMENT
680	INSTALL RUBBER MATS IN SONAR COMPARTMENT
690	LIGHT OFF AND TEST COMPLETE SONAR SYSTEM
700	CERTIFY SONAR SYSTEM
710	COMPLETE TRAM SHIP ALTERATION

SINGLE SHIP COMPUTER MODEL INPUT CODING

```
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//             DSNAME=S0717.TRANSIMA
//   EXEC   PGM=TRANSIMA,REGION=340K,TIME=25
//FT05F001 DD DDNAME=SYSIN
//FT06F001 DD  SYSOUT=A,DCB=(RECFM=FA,BLKSIZE=133),SPACE=(CYL
//FT03F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),
//             DSN=&KJLE,SPACE=(CYL,(1,1)),
//             DCB=(RECFM=FB,LRECL=132,BLKSIZE=3960)
//FT04F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),
//             DSN=&JTPE,SPACE=(CYL,(1,1)),
//             DCB=(RECFM=FB,LRECL=132,BLKSIZE=3960)
//FT08F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),
//             DSN=&JSAF,SPACE=(CYL,(1,1)),
//             DCB=(RECFM=FB,LRECL=86,BLKSIZE=1720)
//SYSIN  DD    *
,-0123456789
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     T 3 C 4 S 5 B 6 G 10 L 11 SERVICE 21 EVENTS 22
  DAYS 23 (  101 ) 102 NOEDIT 29 MAXSTRING 30
+ 103 / 104 ELEMENT 105 ELEMENT LOG 0 NOEDIT MAXSTRING 999 0
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SERVICE TIMES
DAYS
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0.0       4.7       0.1       5.0       0.9       5.0       1.0       5.3
0.0       4.5       0.2       5.0       0.8       5.0       1.0       5.5
0.0       11.2      0.1       11.2      0.5       12.2      0.9       13.2
1.0       14.0
0.0       2.0       0.3       2.0       0.31      2.3       0.6       2.3
0.61      2.5       0.8       2.5       0.81      2.8       1.0       2.8
0.0       2.0       0.1       2.0       0.11      4.0       0.5       4.0
0.51      6.0       0.8       6.0       0.81      8.0       1.0       8.0
0.0       2.5       1.0       4.0
0.0       4.0       1.0       6.0
0.0       2.5       0.1       3.0       0.9       3.0       1.0       3.5
0.0       4.2       0.5       4.2       0.51      4.5       0.7       4.5
0.71      4.7       0.9       4.7       1.0       4.8
0.0       4.0       0.1       6.0       0.4       7.0       0.8       8.0
1.0       8.3
0.0       5.3       0.2       6.0       0.8       6.0       1.0       6.7
0.0       1.7       0.8       1.7       1.0       2.0
0.0       16.8      0.1       16.8      0.11      19.2      0.6       19.2
0.61      21.1      0.8       21.1      0.81      23.0      1.0       23.0
0.0       4.0       0.75      4.0       1.0       6.0
0.0       0.8       0.2       1.0       0.7       1.0       1.0       1.2
0.0       7.5       0.2       7.5       0.21      8.7       0.5       8.7
0.51      10.0      0.9       10.0      0.91      11.2      1.0       11.2
0.0       1.6       1.0       3.0
0.0       6.75      1.0       9.4
0.0       2.5       1.0       4.0
0.0       2.2       0.1       2.2       0.11      2.5       0.8       2.5
0.81      3.1       1.0       3.1
0.0     5.0         0.2       5.0       0.21      6.3       0.8       6.3
0.81      7.8       1.0       7.8
0.0       1.6       0.75      1.6       1.0       2.0
0.0       1.0       1.0       1.5
0.0       5.8       0.2       5.8       0.7       6.7       1.0       8.3
0.0       4.0       1.0       4.3
0.0       5.7       1.0       5.7
0.0       5.4       0.04      7.8       0.14      8.5       0.24      9.1
0.74      9.4       0.84      10.1      0.94      10.3      1.0       10.7
0.0       7.1       0.33      7.1       0.34      7.5       0.66      7.5
0.67      8.0       1.0       8.4
0.0       4.0       0.7       4.8       0.71      5.2       0.9       5.2
0.91      5.5       1.0       5.5
0.0       7.6       0.2       7.6       0.21      8.2       0.6       8.2
0.61      8.9       1.0       8.9
0.0       2.0       1.0       2.2
0.0       5.0       0.9       9.0       1.0       10.0
0.0       23.0      0.1       23.0      0.11      25.0      0.7       25.0
0.71      26.0      0.8       26.0      0.81      27.0      0.9       27.0
0.91      29.0      1.0       30.0
0.0       2.0       1.0       4.0
0.0       2.0       1.0       2.0
0.0       4.0       1.0       4.0
0.0       3.0       1.0       5.0
0.0       5.0       0.5       5.0       0.51      10.0      1.0       10.0
0.0       4.4       0.33      4.4       0.34      5.0       0.66      5.0
0.67      5.3       1.0       5.3
0.0       1.0       0.1       1.0       0.11      1.2       0.6       1.3
0.61      1.6       0.9       1.6       0.91      2.0       1.0       2.0
0.9       1.6       0.91      2.0       1.0       2.0
```

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0.0     0.1    1.0     0.3
0.0     0.6    1.0     0.8
0.0     1.8    1.0     2.2
0.0     0.4    1.0     0.7
0.0     1.4    1.0     1.8
0.0     1.8    0.8     2.3    1.0     3.0
0.0     2.0    1.0     5.0
0.0     3.0    1.0     5.0
0.0     3.0    1.0     5.0
0.0     5.0    1.0     8.0
0.0     2.0    1.0     3.5
0.0     1.0    1.0     3.0
0.0     4.5    0.2     4.9    0.21    5.6    0.8     5.6
0.81    6.5    0.9     6.8    0.91    7.4    1.0     7.4
0.0     0.5    0.2     1.2    0.7     2.0    0.9     2.8
1.0     3.0
0.0     0.8    0.1     1.3    0.2     1.8    0.7     1.8
0.71    2.0    1.0     2.0
0.0     1.2    0.2     1.3    0.4     1.5    0.8     1.6
1.0     1.9
0.0     1.0    1.0     2.5
0.0     6.4    0.1     7.1    0.5     10.3   0.8     16.0
1.0     19.2
0.0     1.3    0.2     1.4    0.8     1.5    1.0     3.0
0.0     14.0   0.1     21.0   0.20    25.0   0.5     27.0
0.6     30.0   0.7     32.0   1.0     39.0
0.0     14.0   0.7     14.0   1.0     25.0
0.0     1.3    1.0     1.7
0.0     1.75   0.1     2.0    0.8     2.0    1.0     2.5
0.0     1.5    1.0     1.5
0.0     1.0    1.0     1.0
0.0     2.0    1.0     2.0
0.0     21.0   1.0     21.0
EVENTS
  1   0 0001            1            1             41101       2
  1   0 0001            1            1             41104       1
  1   0 0001            1            1             41105       3
  1   0 0001            1            1             41106       6
  1   0 0001            1            1             41350       2
  1   0 0001            1            1             41701       1
  1   0 0001            1            1             41702       1
  1   0 0001            1            1             41703       4
  1   0 0001            1            1             41704       3
  1   0 0001            1            1             41705       4
  1   0 0001            1            1             42601       1
  1   0 0001            1            1             42605       6
  1   0 0001            1            1             42900       2
  1   0 0001            1            1             43107       2
  1   0 0001            1            1             43607       4
  1   0 0001            1            1             43610       1
  1   0 0001            1            1             45101       3
  1   0 0001            1            1             45103       6
  1   0 0001            1            1             45108       2
  1   0 0001            1            1             45111       2
  1   0 0001            1            1             45120      12
  1   0 0001            1            1             45605       1
  1   0 0001            1            1             45606       4
  1   0 0001            1            1             46406       6
  1   0 0001            1            1             46713      12
  1   0 0001            1            1             47102       1
  1   0 0001            1            1             47103       1
  1   0 0001            1            1             47104       8
  1   0 0001            1            1             47202       3
  1   0 0001            1            1             47205       7
  1   0 0001            1            1               710       1
  1   0 0001            1            1               999      30
  19999 2359           12
****************************************************************
 THROUGHPUT   1  LOAD   2  TIME   3
 TYPE  4   TYPES  4
 STEP  5   STEPS  5
 TO    6
 ELEMENT 7 ELEMENTS 7  OPEL 7 OPELS 7
 DELAY 8
 DISTRIBUTION 9  DISTRIBUTIONS 9
 ELAPSED  10
 DAY 11  D  11  DAYS  11
 HOUR 12 HOURS 12 HR 12  HRS 12  H 12
MIN 13  M 13 MINUTES  13  MNS 13 MN 13 MINS 13
 SEC 14  SECS 14  S  14   SECOND 14 SECONDS 14
 / 15 TITLE 16 FROM 17 ALL 18 END 19 HEADING 20
 HEADINGS 20 HEADINGS
HEADING   ALL MANPOWER POOL LEVELS ARE SHOWN IN MEN
OUTPUT REPORTS FOR SIMULATION OF TRAM OVERHAUL (SINGLE SHIP)
LOAD
TITLE  WORKCENTER 1101  AVAILABLE (UNASSIGNED) MANPOWER
ELEMENT 1
TYPE 41101  DISTRIBUTION 0 / STEPS OF 1 / 34
FROM DAY 0 TO DAY 9999
TITLE  WORKCENTER 1104 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY C TO DAY  9999
ELEMENT 1
TYPE 41104  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 1105 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 41105  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 1106 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY C TO DAY  9999
ELEMENT 1
TYPE 41106  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 1350  AVAILABLE (UNASSIGNED) MANPOWER
FROM DAY 0 TO DAY 9999
ELEMENT 1
TYPE 41350  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 1701 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY C TO DAY  9999
ELEMENT 1
TYPE 41701  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 1702 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY C TO DAY  9999
ELEMENT 1
TYPE 41702  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 1703 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY C TO DAY  9999
ELEMENT 1
TYPE 41703  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 1704 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY C TO DAY  9999
ELEMENT 1
TYPE 41704  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 1705 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY C TO DAY  9999
ELEMENT 1
TYPE 41705  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 2601 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY C TO DAY  9999
ELEMENT 1
TYPE 42601  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 2605 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY C TO DAY  9999
ELEMENT 1
TYPE 42605  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 2900 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY C TO DAY  9999
ELEMENT 1
TYPE 42900  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 3107 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 43107  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 3607 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY C TO DAY  9999
ELEMENT 1
```

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TYPE 43607  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 3610 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 43610  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 5101 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 45101  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 5103 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 45103  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 5108 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 45108  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 5111  AVAILABLE (UNASSIGNED) MANPOWER
FROM DAY 0 TO DAY 9999
ELEMENT 1
TYPE 45111  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 5120 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 45120  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 5605 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 45605  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 5606 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 45606  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 6406 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 46406  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 6713 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 46713  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 7102 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 47102  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 7103 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 47103  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 7104 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 47104  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE  WORKCENTER 7202 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 47202  DISTRIBUTION 0 / STEPS OF 1 / 34
TITLE WORKCENTER 7205 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 47205  DISTRIBUTION 0 / STEPS OF 1 / 34
TIME
TITLE OVERALL JOB TIME START TO FINISH
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 9000
ELAPSED DISTRIBUTION 50 DAYS / STEPS OF 1 DAYS / 110 DAYS
DELAY DISTRIBUTION 50 DAYS / STEPS OF 1 DAYS / 110 DAYS
TITLE   9001 COMPLETION PHASE 1
FROM DAY 0 TO DAY 9999
ELEMENT 1
TYPE 9001
```

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ELAPSED DISTRIBUTION 1 DAY / STEPS OF 1 DAY / 60 DAYS
DELAY DISTRIBUTION 1 DAY / STEPS OF 1 DAY / 60 DAYS
TITLE   9002 COMPLETION PHASE 2
FROM DAY 0 TO DAY 9999
ELEMENT 1
TYPE 9C02
ELAPSED DISTRIBUTION 1 DAY / STEPS OF 1 DAY / 60 DAYS
DELAY DISTRIBUTION 1 DAY / STEPS OF 1 DAY / 60 DAYS
TITLE   9003 COMPLETION PHASE 3
FROM DAY 0 TO DAY 9999
ELEMENT 1
TYPE 9C03
ELAPSED DISTRIBUTION 1 DAY / STEPS OF 1 DAY / 60 DAYS
DELAY DISTRIBUTION 1 DAY / STEPS OF 1 DAY / 60 DAYS
TITLE   TASK 321    PREPARE CABLES  (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
 ELEMENT 1
 TYPE 5321 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 321 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6321 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 322    PROVIDE CABLE PLANS  (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
 ELEMENT 1
 TYPE 5322 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 322 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6322 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 323    PROVIDE CABLE MARKERS  (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
 ELEMENT 1
 TYPE 5323 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 323 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6323 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 330    PREFABRICATE PIPING  (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
 ELEMENT 1
 TYPE 5330 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 330 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6330 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 341    CHECK FOUNDATION PLANS   (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
 ELEMENT 1
 TYPE 5341 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 341 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6341 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 342    FABRICATE FOUNDATIONS  (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
 ELEMENT 1
 TYPE 5342 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 342 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6342 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 343    WELD FOUNDATIONS  (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
 ELEMENT 1
 TYPE 5343 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 343 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6343 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 350    FABRICATE BULKHEAD  (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
 ELEMENT 1
 TYPE 5350 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 350 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6350 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 370    PROVIDE ACCESS  (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
 ELEMENT 1
 TYPE 5370 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 370 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6370 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 380    DISCONNECT EQUIPMENT  (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
 ELEMENT 1
 TYPE 5380 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 380 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6380 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 391    RIPOUT BULKHEAD  (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
 ELEMENT 1
 TYPE 5391 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 391 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6391 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 393    REMOVE FIREMAIN  (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
 ELEMENT 1
 TYPE 5393 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 393 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6393 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 400    RIPOUT FOUNDATIONS  (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
 ELEMENT 1
 TYPE 5400 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 400 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6400 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 410    RIPOUT CABLES  (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
 ELEMENT 1
 TYPE 5410 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 410 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6410 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 421 LT MANNING CABLE INST  (DELAY=SLACK)
  FROM  DAY 0 TO DAY  9999
 ELEMENT 1
 TYPE 5421 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 421 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6421 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 422 HEAVY MANNING CABLE INST (DELAY=SLACK)
  FROM  DAY 0 TO DAY  9999
 ELEMENT 1
 TYPE 5422 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 422 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6422 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE TASK 424 COMMENCE CABLE INST (DELAY=SLACK)
  FROM  DAY 0 TO DAY  9999
 ELEMENT 1
 TYPE 5424 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 424 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6424 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 431    INSTALL BULKHEAD  (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
 ELEMENT 1
 TYPE 5431 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 431 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6431 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE TASK 432 COMPLETE BULKHEAD INST (DELAY=SLACK)
  FROM  DAY 0 TO DAY  9999
 ELEMENT 1
 TYPE 5432 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 432 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6432 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 440    INSTALL FOUNDATIONS  (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
 ELEMENT 1
 TYPE 5440 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 440 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6440 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE TASK 450 REMOVE MG SETS (DELAY=SLACK)
  FROM  DAY 0 TO DAY  9999
 ELEMENT 1
 TYPE 5450 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 450 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6450 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE TASK 460 REFURBISH & REWIND MG SETS (DELAY=SLACK)
  FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 5460 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 460 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6460 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE TASK 461 BENCH TEST MG SETS (DELAY=SLACK)
  FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 5461 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 461 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6461 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE TASK 471 REMOVE VENT & A/C DUCTS (DELAY=SLACK)
  FROM  DAY 0 TO DAY  9999
 ELEMENT 1
 TYPE 5471 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 471 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6471 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 473    REMOVE VENT MOTOR  (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
 ELEMENT 1
 TYPE 5473 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 473 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6473 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 480    PREFABRICATE VENTS  (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
  ELEMENT 1
  TYPE 5480 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
  TITLE TASK 480 AWAIT (DELAY = SLACK)
  FROM DAY 0 TO DAY 9999
  ELEMENT 1
  TYPE 6480 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE    TASK 500    PREFABRICATE WORKBENCH  (DELAY = SLACK)
   FROM  DAY 0 TO DAY  9999
  ELEMENT 1
  TYPE 5500 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
  TITLE TASK 500 AWAIT (DELAY = SLACK)
  FROM DAY 0 TO DAY 9999
  ELEMENT 1
  TYPE 6500 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE    TASK 510    FABRICATE PULL BOX  (DELAY = SLACK)
   FROM  DAY 0 TO DAY  9999
  ELEMENT 1
  TYPE 5510 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
  TITLE TASK 510 AWAIT (DELAY = SLACK)
  FROM DAY 0 TO DAY 9999
  ELEMENT 1
  TYPE 6510 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE    TASK 520    MODIFY PSK BOX  (DELAY = SLACK)
   FROM  DAY 0 TO DAY  9999
  ELEMENT 1
  TYPE 5520 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
  TITLE TASK 520 AWAIT (DELAY = SLACK)
  FROM DAY 0 TO DAY 9999
  ELEMENT 1
  TYPE 6520 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE    TASK 531    MODIFY PIPING  (DELAY = SLACK)
   FROM  DAY 0 TO DAY  9999
  ELEMENT 1
  TYPE 5531 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
  TITLE TASK 531 AWAIT (DELAY = SLACK)
  FROM DAY 0 TO DAY 9999
  ELEMENT 1
  TYPE 6531 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE    TASK 532    INSULATE PIPING  (DELAY = SLACK)
   FROM  DAY 0 TO DAY  9999
  ELEMENT 1
  TYPE 5532 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
  TITLE TASK 532 AWAIT (DELAY = SLACK)
  FROM DAY 0 TO DAY 9999
  ELEMENT 1
  TYPE 6532 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE TASK 540 INSTALL FIREMAIN & HP AIR SYS (DELAY=SLACK)
   FROM  DAY 0 TO DAY  9999
  ELEMENT 1
  TYPE 5540 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
  TITLE TASK 540 AWAIT (DELAY = SLACK)
  FROM DAY 0 TO DAY 9999
  ELEMENT 1
  TYPE 6540 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE TASK 550 INSTALL VENT & A/C DUCTS (DELAY=SLACK)
   FROM  DAY 0 TO DAY  9999
  ELEMENT 1
  TYPE 5550 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
  TITLE TASK 550 AWAIT (DELAY = SLACK)
  FROM DAY 0 TO DAY 9999
  ELEMENT 1
  TYPE 6550 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE    TASK 561    MODIFY UBFC SYSTEM  (DELAY = SLACK)
   FROM  DAY 0 TO DAY  9999
  ELEMENT 1
  TYPE 5561 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
  TITLE TASK 561 AWAIT (DELAY = SLACK)
  FROM DAY 0 TO DAY 9999
  ELEMENT 1
  TYPE 6561 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE    TASK 563   CHECKOUT UBFC SYSTEM  (DELAY = SLACK)
   FROM  DAY 0 TO DAY  9999
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 ELEMENT 1
 TYPE 5563 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 563 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6563 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE    TASK 564     COLD WIRE CHECK UBFC   (DELAY = SLACK)
  FROM   DAY 0 TO DAY   9999
 ELEMENT 1
 TYPE 5564 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 564 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6564 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE    TASK 570     MODIFY POWER SYSTEM   (DELAY = SLACK)
  FROM   DAY 0 TO DAY   9999
 ELEMENT 1
 TYPE 5570 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 570 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6570 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE TASK 581 DISASSEMBLE MOUNT SONAR CONSOLE (DELAY=SLACK)
  FROM   DAY 0 TO DAY   9999
 ELEMENT 1
 TYPE 5581 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 581 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6581 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE    TASK 582     MODIFY CONSOLE CABINETS   (DELAY = SLACK)
  FROM   DAY 0 TO DAY   9999
 ELEMENT 1
 TYPE 5582 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 582 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6582 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE TASK 583 FIELD CHANGES & VIS REPAIRS (DELAY=SLACK)
  FROM   DAY 0 TO DAY   9999
 ELEMENT 1
 TYPE 5583 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 583 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6583 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE TASK 591 FINAL VIS REPAIRS TO CONSOLES   (DELAY=SLACK)
  FROM   DAY 0 TO DAY   9999
 ELEMENT 1
 TYPE 5591 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 591 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6591 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE TASK 592 Q/A CHECK OF CONSOLES (DELAY=SLACK)
  FROM   DAY 0 TO DAY   9999
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 TYPE 5592 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 592 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6592 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE TASK 593 HOOK UP & MODIFY CONSOLES (DELAY=SLACK)
  FROM   DAY 0 TO DAY   9999
 ELEMENT 1
 TYPE 5593 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 593 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6593 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE TASK 601 COMMENCE EQUIP INSTALLATION (DELAY=SLACK)
  FROM   DAY 0 TO DAY   9999
 ELEMENT 1
 TYPE 5601 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 601 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6601 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 602    COMMENCE INSTALLATION  (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
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 TYPE 5602 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 602 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6602 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 603    COMPLETE CONNECTING  (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
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 TYPE 5603 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 603 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6603 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 604    COMMENCE CONNECTING  (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
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 TYPE 5604 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 604 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6604 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 605    COMMENCE WIRECHECK  (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
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 TYPE 5605 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 605 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
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 TYPE 6605 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 606    COMPLETE WIRECHECK  (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
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 TYPE 5606 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 606 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6606 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 612    MODIFY LIGHTING  (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
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 TYPE 5612 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 612 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6612 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE TASK 621 PAINT MOTOR GENERATOR SETS  (DELAY=SLACK)
  FROM DAY 0 TO DAY 9999
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 TYPE 5621 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 621 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
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 TYPE 6621 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE TASK 625 INSTALL MOTOR GENERATOR SETS (DELAY=SLACK)
  FROM DAY 0 TO DAY 9999
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 TYPE 5625 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 625 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
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 TYPE 6625 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 640    CLOSE ACCESSES  (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
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 TYPE 5640 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 640 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
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 TYPE 6640 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 650     TILE DECK  (DELAY = SLACK)
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 TYPE 5650 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 650 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6650 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 660     PREPARE DECK FOR MATTING  (DELAY = SLACK
  FROM  DAY 0 TO DAY  9999
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 TYPE 5660 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 660 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
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 TYPE 6660 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 670     PAINT COMPARTMENT  (DELAY = SLACK)
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 TYPE 5670 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 670 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
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 TYPE 6670 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 680     INSTALL RUBBER MATS  (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
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 TYPE 5680 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 680 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6680 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 690     LIGHT OFF AND TEST INSTALLATION  (DELAY
  FROM  DAY 0 TO DAY  9999
 ELEMENT 1
 TYPE 5690 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 690 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6690 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
TITLE   TASK 700     CERTIFY INSTALLATION  (DELAY = SLACK)
  FROM  DAY 0 TO DAY  9999
 ELEMENT 1
 TYPE 5700 ELAPSED DISTRIBUTION 1 D / STEPS OF 1 D / 30 D
 TITLE TASK 700 AWAIT (DELAY = SLACK)
 FROM DAY 0 TO DAY 9999
 ELEMENT 1
 TYPE 6700 DELAY DISTRIBUTION  1 D / STEPS OF 1 D / 30 D
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TRIPLE SHIP COMPUTER MODEL INPUT CODING

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//             DSN=&KJLE,SPACE=(CYL,(1,1)),
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(25324) S (26324)
(35324) S (36324)
(15325) S (16325)
(25325) S (26325)
(35325) S (36325)
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(16324) G 5(45103)
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(26325) G 6(45103)
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(16326) G 6(45103)
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(36326) G 6(45103)
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(26324) + (26325) + (26326) C (26321)
(36324) + (36325) + (36326) C (36321)
(400024) B
(15520) T 1
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(15570) T 4
(15380) T 5
(15370) T 6
(15391) T 7
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(15450) T 13
(15612) T 14
(15400) T 15
(15341) T 16
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(15343) T 18
(15440) T 19
(15393) T 20
(15431) T 21
(15540) T 22
(15471) T 23
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(15326) T 31
(15581) T 32
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(15592) T 35
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(15461) T 41
(15621) T 42
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(15602) T 49
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(15606) T 51
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(15690) T 61
(15700) T 62
(15424) T 26
(15564) T 63
(15432) T 64
(10611) T 65
(10623) T 66
(10624) T 66
(10423) T 67
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(15596) T 36
(15584) T 34
(15585) T 34
(15423) T 28
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(25500) T 12
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(25400)  T  15
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(25625)  T  45
(25563)  T  47
(25601)  T  48
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(35400)  T  15
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(35585) T 34
(35423) T 28
(35428) T 28
(35429) T 28
(10997) T 69
(20996) T 70
(20997) T 71
(30996) T 72
(30997) T 73
SERVICE TIMES
DAYS
0.0      3.7      1.0      3.7
0.0      4.7      0.1      5.0      0.9      5.0      1.0      5.3
0.0      4.5      0.2      5.0      0.8      5.0      1.0      5.5
0.0      11.2     0.1      11.2     0.5      12.2     0.9      13.2
1.0      14.0
0.0      2.0      0.3      2.0      0.31     2.3      0.6      2.3
0.61     2.5      0.8      2.5      0.81     2.8      1.0      2.8
0.0      2.0      0.1      2.0      0.11     4.0      0.5      4.0
0.51     6.0      0.8      5.0      0.81     8.0      1.0      8.0
0.0      2.5      1.0      4.0
0.0      4.0      1.0      6.0
```

0.0	2.5	0.1	3.0	0.9	3.0	1.0	3.5
0.0	4.2	0.5	4.2	0.51	4.5	0.7	4.5
0.71	4.7	0.9	4.7	1.0	4.8		
0.0	4.0	0.1	6.0	0.4	7.0	0.8	8.0
1.0	8.3						
0.0	5.3	0.2	6.0	0.8	6.0	1.0	6.7
0.0	1.7	0.8	1.7	1.0	2.0		
0.0	16.8	0.1	16.8	0.11	19.2	0.6	19.2
0.61	21.1	0.8	21.1	0.81	23.0	1.0	23.0
0.0	4.0	0.75	4.0	1.0	6.0		
0.0	0.8	0.2	1.0	0.7	1.0	1.0	1.2
0.0	7.5	0.2	7.5	0.21	8.7	0.5	8.7
0.51	10.0	0.9	10.0	0.91	11.2	1.0	11.2
0.0	1.6	1.0	3.0				
0.0	6.75	1.0	9.4				
0.0	2.5	1.0	4.0				
0.0	2.2	0.1	2.2	0.11	2.5	0.8	2.5
0.81	3.1	1.0	3.1				
0.0	5.0	0.2	5.0	0.21	6.3	0.8	6.3
0.81	7.8	1.0	7.8				
0.0	1.6	0.75	1.6	1.0	2.0		
0.0	1.0	1.0	1.5				
0.0	5.8	0.2	5.8	0.7	6.7	1.0	8.3
0.0	4.0	1.0	4.3				
0.0	5.7	1.0	5.7				
0.0	5.4	0.04	7.8	0.14	8.5	0.24	9.1
0.74	9.4	0.84	10.1	0.94	10.3	1.0	10.7
0.0	7.1	0.33	7.1	0.34	7.5	0.66	7.5
0.67	8.0	1.0	8.4				
0.0	4.0	0.7	4.8	0.71	5.2	0.9	5.2
0.91	5.5	1.0	5.5				
0.0	7.6	0.2	7.6	0.21	8.2	0.6	8.2
0.61	8.9	1.0	8.9				
0.0	2.0	1.0	2.2				
0.0	5.0	0.9	9.0	1.0	10.0		
0.0	23.0	0.1	23.0	0.11	25.0	0.7	25.0
0.71	26.0	0.8	26.0	0.81	27.0	0.9	27.0
0.91	29.0	1.0	30.0				
0.0	2.0	1.0	4.0				
0.0	2.0	1.0	2.0				
0.0	4.0	1.0	4.0				
0.0	3.0	1.0	5.0				
0.0	5.0	0.5	5.0	0.51	10.0	1.0	10.0
0.0	4.4	0.33	4.4	0.34	5.0	0.66	5.0
0.67	5.3	1.0	5.3				
0.0	1.0	0.1	1.0	0.11	1.2	0.6	1.3
0.61	1.6	0.9	1.6	0.91	2.0	1.0	2.0
0.9	1.6	0.91	2.0	1.0	2.0		
0.0	0.1	1.0	0.3				
0.0	0.6	1.0	0.8				
0.0	1.8	1.0	2.2				
0.0	0.4	1.0	0.7				
0.0	1.4	1.0	1.8				
0.0	1.8	0.8	2.3	1.0	3.0		
0.0	2.0	1.0	5.0				
0.0	3.0	1.0	5.0				
0.0	3.0	1.0	5.0				
0.0	5.0	1.0	8.0				
0.0	2.0	1.0	3.5				
0.0	1.0	1.0	3.0				
0.0	4.5	0.2	4.9	0.21	5.6	0.8	5.6
0.81	6.5	0.9	6.8	0.91	7.4	1.0	7.4
0.0	0.5	0.2	1.2	0.7	2.0	0.9	2.8
1.0	3.0						
0.0	0.8	0.1	1.3	0.2	1.8	0.7	1.8
0.71	2.0	1.0	2.0				
0.0	1.2	0.2	1.3	0.4	1.5	0.8	1.6
1.0	1.9						
0.0	1.0	1.0	2.5				
0.0	6.4	0.1	7.1	0.5	10.3	0.8	16.0
1.0	19.2						
0.0	1.3	0.2	1.4	0.8	1.5	1.0	3.0

```
0.0    14.0   0.1    21.0   0.20   25.0   0.5    27.0
0.6    30.0   0.7    32.0   1.0    39.0
0.0    14.0   0.7    14.0   1.0    25.0
0.0    1.3    1.0    1.7
0.0    1.75   0.1    2.0    0.8    2.0    1.0    2.5
0.0    1.5    1.0    1.5
0.0    1.0    1.0    1.0
0.0    2.0    1.0    2.0
0.0    21.0   1.0    21.0
0.0    18.0   1.0    18.0
0.0    12.0   1.0    12.0
0.0    30.0   1.0    30.0
0.0    24.0   1.0    24.0
0.0    42.0   1.0    42.0
EVENTS
   1    0 0001           1            1           41101      6
   1    0 0001           1            1           41104      3
   1    0 0001           1            1           41105      9
   1    0 0001           1            1           41106     18
   1    0 0001           1            1           41350      6
   1    0 0001           1            1           41701      3
   1    0 0001           1            1           41702      3
   1    0 0001           1            1           41703     12
   1    0 0001           1            1           41704      9
   1    0 0001           1            1           41705     12
   1    0 0001           1            1           42601      3
   1    0 0001           1            1           42605     18
   1    0 0001           1            1           42900      6
   1    0 0001           1            1           43107      6
   1    0 0001           1            1           43607     12
   1    0 0001           1            1           43610      3
   1    0 0001           1            1           45101      9
   1    0 0001           1            1           45103     18
   1    0 0001           1            1           45108      6
   1    0 0001           1            1           45111      6
   1    0 0001           1            1           45120     36
   1    0 0001           1            1           45605      3
   1    0 0001           1            1           45606     12
   1    0 0001           1            1           46406     18
   1    0 0001           1            1           46713     20
   1    0 0001           1            1           47102      3
   1    0 0001           1            1           47103      3
   1    0 0001           1            1           47104     24
   1    0 0001           1            1           47202      9
   1    0 0001           1            1           47205     21
   1    0 0001           1            1             710      1
   1    0 0001           1            1             999     10
  19999 2359            12
**********************************************************************
 THROUGHPUT  1  LOAD  2  TIME  3
 TYPE  4  TYPES  4
 STEP  5  STEPS  5
 TO   6
 ELEMENT 7 ELEMENTS 7  OPEL 7 OPELS 7
 DELAY 8
 DISTRIBUTION 9  DISTRIBUTIONS 9
 ELAPSED  10
 DAY 11  D  11  DAYS  11
 HOUR 12 HOURS 12 HR 12  HRS 12  H 12
MIN 13  M 13 MINUTES  13  MNS 13 MN 13 MINS 13
 SEC 14  SECS 14  S  14   SECOND 14 SECONDS 14
 / 15 TITLE 16 FROM 17 ALL 18 END 19 HEADING 20
 HEADINGS 20 HEADINGS
HEADING ALL MANPOWER POOL LEVELS ARE SHOWN IN MEN UNITS
LOAD
TITLE  WORKCENTER 1101  AVAILABLE (UNASSIGNED) MANPOWER
ELEMENT 1
TYPE 41101
DISTRIBUTION 0 / 10 / 20
FROM DAY 0 TO DAY 9999
TITLE  WORKCENTER 1104 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
```

```
ELEMENT 1
TYPE 41104 DISTRIBUTION 0 / 10
TITLE  WORKCENTER 1105 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 41105 DISTRIBUTION 1 / STEPS OF 10 / 30
TITLE  WORKCENTER 1106 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 41106 DISTRIBUTION 0 / STEPS OF 10 / 40
TITLE  WORKCENTER 1350  AVAILABLE (UNASSIGNED) MANPOWER
FROM DAY 0 TO DAY 9999
ELEMENT 1
TYPE 41350
DISTRIBUTION 0 / 10 / 20
TITLE  WORKCENTER 1701 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 41701 DISTRIBUTION 0 / 10
TITLE  WORKCENTER 1702 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 41702  DISTRIBUTION 0 / STEPS OF 10 / 10
TITLE  WORKCENTER 1703 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 41703  DISTRIBUTION 0/ STEPS OF 10 / 40
TITLE  WORKCENTER 1704 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 41704  DISTRIBUTION 0 / STEPS OF 10 / 30
TITLE  WORKCENTER 1705 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 41705  DISTRIBUTION 0 / STEPS OF 10 / 40
TITLE  WORKCENTER 2601 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 42601  DISTRIBUTION 0 / 10
TITLE  WORKCENTER 2605 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 42605  DISTRIBUTION 1 / STEPS OF 10 / 40
TITLE  WORKCENTER 2900 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 42900  DISTRIBUTION 0 / 10 / 20
TITLE  WORKCENTER 3107 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 43107  DISTRIBUTION 0 / 10 / 20
TITLE  WORKCENTER 3607 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 43607  DISTRIBUTION 0 / STEPS OF 10 / 40
TITLE  WORKCENTER 3610 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 43610  DISTRIBUTION 0 / 10
TITLE  WORKCENTER 5101 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 45101  DISTRIBUTION 0 / STEPS OF 10 / 30
TITLE  WORKCENTER 5103 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 45103  DISTRIBUTION 0 / STEPS OF 10 / 170
TITLE  WORKCENTER 5108 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 45108  DISTRIBUTION 0 / STEPS OF 10 / 20
TITLE  WORKCENTER 5111  AVAILABLE (UNASSIGNED) MANPOWER
```

```
FROM DAY 0 TO DAY 9999
ELEMENT 1
TYPE 45111
DISTRIBUTION 0 / 10 / 20
TITLE  WORKCENTER 5120 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 45120  DISTRIBUTION 0 / STEPS OF 10 / 180
TITLE  WORKCENTER 5605 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 45605  DISTRIBUTION 0 / 10
TITLE  WORKCENTER 5606 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 45606  DISTRIBUTION 1 / STEPS OF 1 / 36
TITLE  WORKCENTER 6406 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 46406  DISTRIBUTION 0 / STEPS OF 10 / 60
TITLE  WORKCENTER 6713 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 46713  DISTRIBUTION 0 / STEPS OF 10 / 120
TITLE  WORKCENTER 7102 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 47102  DISTRIBUTION 0 / 10
TITLE  WORKCENTER 7103 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 47103  DISTRIBUTION 0 / 10
TITLE  WORKCENTER 7104 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 47104  DISTRIBUTION 0 / STEPS OF 10 / 80
TITLE  WORKCENTER 7202 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 47202  DISTRIBUTION 0 / STEPS OF 10 / 30
TITLE  WORKCENTER 7205 AVAILABLE (UNASSIGNED) MANPOWER
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 47205  DISTRIBUTION 0 / STEPS OF 10 / 70
TIME
TITLE  OVERALL THREE SHIP JOB TIME START TO FINISH
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 90000
ELAPSED DISTRIBUTION 65 DAYS / STEPS OF 1 DAYS / 165 DAYS
DELAY DISTRIBUTION 65 DAYS / STEPS OF 1 DAYS / 165 DAYS
TITLE SHIP 1 JOB TIME START TO FINISH
  FROM DAY 0 TO DAY 9999
ELEMENT 1
TYPE 10000
ELAPSED DISTRIBUTION 65 DAYS / STEPS OF 1 DAYS / 165 DAYS
DELAY DISTRIBUTION 65 DAYS / STEPS OF 1 DAYS / 165 DAYS
TITLE SHIP 2 JOB TIME START TO FINISH
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 20000
ELAPSED DISTRIBUTION 65 DAYS / STEPS OF 1 DAYS / 165 DAYS
DELAY DISTRIBUTION 65 DAYS / STEPS OF 1 DAYS / 165 DAYS
TITLE SHIP 3 JOB TIME START TO FINISH
  FROM  DAY 0 TO DAY  9999
ELEMENT 1
TYPE 30000
ELAPSED DISTRIBUTION 65 DAYS / STEPS OF 1 DAYS / 165 DAYS
DELAY DISTRIBUTION 65 DAYS / STEPS OF 1 DAYS / 165 DAYS
TITLE  19001 COMPLETION PHASE 1 SHIP 1
FROM DAY 0 TO DAY 9999
ELEMENT 1
```

```
TYPE 19001
ELAPSED DISTRIBUTION 1 DAY / STEPS OF 1 DAY / 40 DAYS
DELAY DISTRIBUTION 1 DAY / STEPS OF 1 DAY / 40 DAYS
TITLE  29001 COMPLETION PHASE 1 SHIP 2
FROM DAY 0 TO DAY 9999
ELEMENT 1
TYPE 29001
ELAPSED DISTRIBUTION 1 DAY / STEPS OF 1 DAY / 40 DAYS
DELAY DISTRIBUTION 1 DAY / STEPS OF 1 DAY / 40 DAYS
TITLE  39001 COMPLETION PHASE 1 SHIP 3
FROM DAY 0 TO DAY 9999
ELEMENT 1
TYPE 39001
ELAPSED DISTRIBUTION 1 DAY / STEPS OF 1 DAY / 40 DAYS
DELAY DISTRIBUTION 1 DAY / STEPS OF 1 DAY / 40 DAYS
TITLE  19002 COMPLETION PHASE 2 SHIP 1
FROM DAY 0 TO DAY 9999
ELEMENT 1
TYPE 19002
ELAPSED DISTRIBUTION 1 DAY / STEPS OF 1 DAY / 40 DAYS
DELAY DISTRIBUTION 1 DAY / STEPS OF 1 DAY / 40 DAYS
TITLE  29002 COMPLETION PHASE 2 SHIP 2
FROM DAY 0 TO DAY 9999
ELEMENT 1
TYPE 29002
ELAPSED DISTRIBUTION 1 DAY / STEPS OF 1 DAY / 40 DAYS
DELAY DISTRIBUTION 1 DAY / STEPS OF 1 DAY / 40 DAYS
TITLE  39002 COMPLETION PHASE 2 SHIP 3
FROM DAY 0 TO DAY 9999
ELEMENT 1
TYPE 39002
ELAPSED DISTRIBUTION 1 DAY / STEPS OF 1 DAY / 40 DAYS
DELAY DISTRIBUTION 1 DAY / STEPS OF 1 DAY / 40 DAYS
TITLE  19003 COMPLETION PHASE 3 SHIP 1
FROM DAY 0 TO DAY 9999
ELEMENT 1
TYPE 19003
ELAPSED DISTRIBUTION 1 DAY / STEPS OF 1 DAY / 40 DAYS
DELAY DISTRIBUTION 1 DAY / STEPS OF 1 DAY / 40 DAYS
TITLE  29003 COMPLETION PHASE 3 SHIP 2
FROM DAY 0 TO DAY 9999
ELEMENT 1
TYPE 29003
ELAPSED DISTRIBUTION 1 DAY / STEPS OF 1 DAY / 40 DAYS
DELAY DISTRIBUTION 1 DAY / STEPS OF 1 DAY / 40 DAYS
TITLE  39003 COMPLETION PHASE 3 SHIP 3
FROM DAY 0 TO DAY 9999
ELEMENT 1
TYPE 39003
ELAPSED DISTRIBUTION 1 DAY / STEPS OF 1 DAY / 40 DAYS
DELAY DISTRIBUTION 1 DAY / STEPS OF 1 DAY / 40 DAYS
END
111111111111111111111111111111111111111111111111111111111111
```

LIST OF REFERENCES

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3. Seigel, S., Nonparametric Statistics for the Behavioral Sciences, p. 47-52, 59-60, 251, McGraw-Hill, 1956.

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A SIMULATION STUDY OF SONAR (SQS-23 TRAM) OVERHAULS ON NAVAL SHIPS

DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Master's Thesis; April 1970

AUTHOR(S) *(First name, middle initial, last name)*

William Lawrence Fulton, Lieutenant Commander, United States Navy

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13. ABSTRACT

A demonstration is provided of using the technique of computer simulation for analyzing scheduling problems in Naval Shipyards. A model is formulated for multiple ship, concurrent, sonar (SQS-23 TRAM) overhauls at the Long Beach Naval Shipyard. This model is an extension of PERT and considers the effect of probabilistic activity times and limited personnel resources. The "TRANSIM" simulator is utilized to assist in predicting the ship overhaul times and manpower utilization under different conditions. Two experiments are conducted which consider changes in relative overhaul commencement dates and modifications to the personnel resource levels. A complete description of the conceptual and computer models and the input coding are included in the report.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
COMPUTER SIMULATION						
SIMULATION						
TRANSIM						
PROJECT NETWORK						
SONAR OVERHAUL						
TRAM (TEST RELIABILITY AND MAINTAINABILITY)						
SQS-23 SONAR						
PERT (PROGRAM EVALUATION AND REVIEW TECHNIQUE)						
CPM (CRITICAL PATH METHOD)						
INDUSTRIAL SCHEDULING						

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